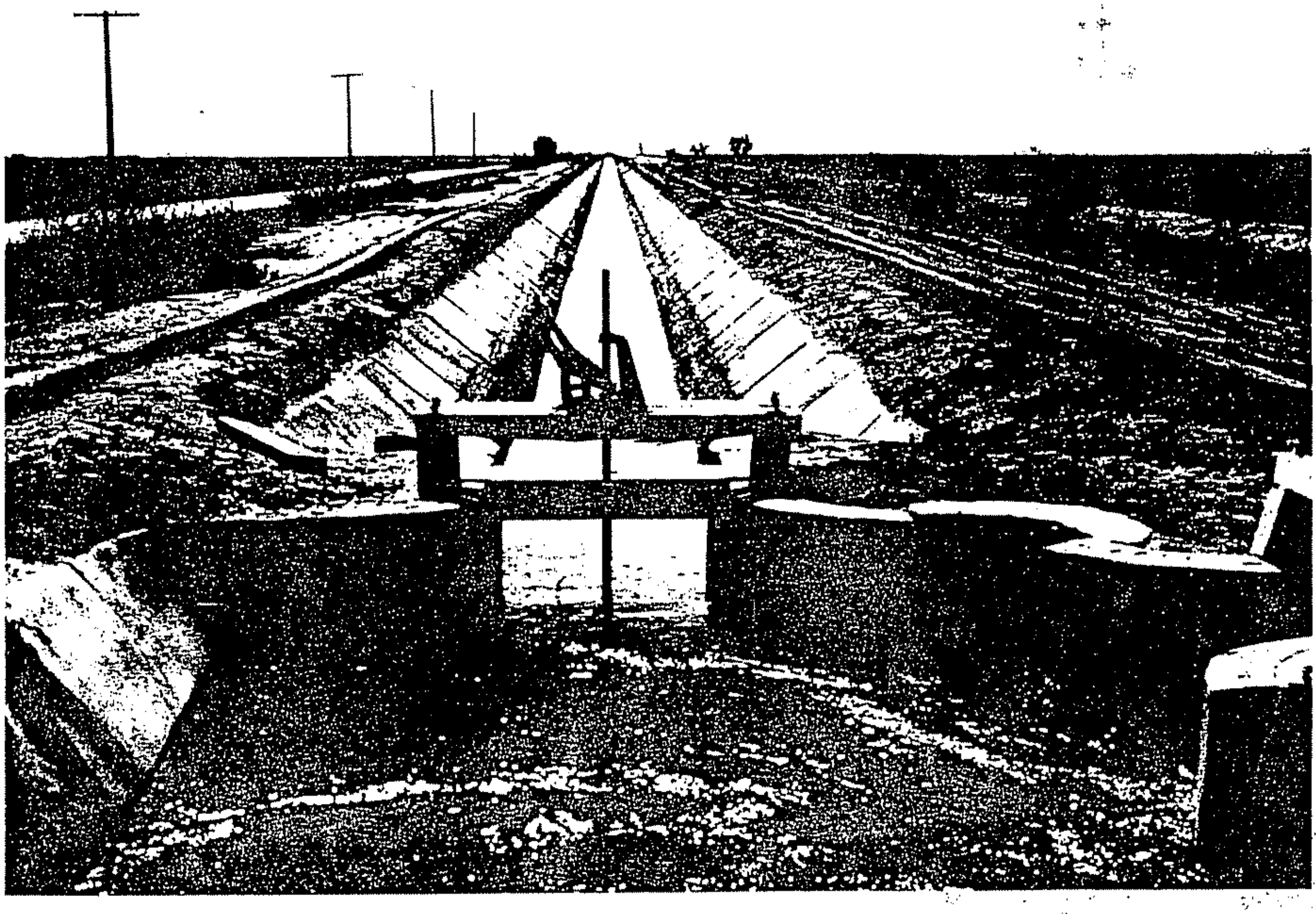
18-3

Investigation Under
California Water Code Section 275
of
USE OF WATER BY IMPERIAL IRRIGATION DISTRICT



State of California

DEPARTMENT OF WATER RESOURCES
Southern District

The Resources Agency

December 1981

State of California
The Resources Agency
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Southern District

Investigation Under California Water Code Section 275 of Use of Water by Imperial Irrigation District

DISTRICT REPORT

December 1981

Copies of this report may be ordered from:

State of California
DEPARTMENT OF WATER RESOURCES
P. O. Box 6598
Los Angeles, CA 90055

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Length	millimetres (mm)	inches (in)	0 03937	25 4
	centimetres (cm) for snow depth	inches (in)	0 3937	2 54
	metres (m)	feet (ft)	3 2808	0 3048
	kilometres (km)	miles (mi)	0 62139	1 6093
Area	square millimetres (mm^2)	square inches (in^2)	0 00155	645 16
	square metres (m^2)	square feet (ft^2)	10 764	0 092903
	hectares (ha)	acres (ac)	2 4710	0 40469
	square kilometres (km^2)	square miles (mi^2)	0 3861	2 590
Volume	litres (L)	gallons (gal)	0 26417	3 7854
	megalitres	million gallons (10^6 gal)	0 26417	3 7854
	cubic metres (m^3)	cubic feet (ft^3)	35 315	0 028317
	cubic metres (m^3)	cubic yards (yd^3)	1 308	0 76455
	cubic dekametres (dam^3)	acre-feet (ac-ft)	0 8107	1 2335
Flow	cubic metres per second (m^3/s)	cubic feet per second (ft^3/s)	35 315	0 028317
	litres per minute (L/min)	gallons per minute (gal/min)	0 26417	3 7854
	litres per day (L/day)	gallons per day (gal/day)	0 26417	3 7854
	megalitres per day (ML/day)	million gallons per day (mgd)	0 26417	3 7854
	cubic dekametres per day (dam^3/day)	acre-feet per day (ac-ft/day)	0 8107	1 2335
Mass	kilograms (kg)	pounds (lb)	2 2046	0 45359
	megagrams (Mg)	tons (short, 2,000 lb)	1 1023	0 90718
Velocity	metres per second (m/s)	feet per second (ft/s)	3 2808	0 3048
Power	kilowatts (kW)	horsepower (hp)	1 3405	0 746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0 14505	6 8948
	kilopascals (kPa)	feet head of water	0 33456	2 989
Specific Capacity	litres per minute per metre drawdown	gallons per minute per foot drawdown	0 08052	12 419
Concentration	milligrams per litre (mg/L)	parts per million (ppm)	1 0	1 0
Electrical Conductivity	microsiemens per centimetre (uS/cm)	micromhos per centimetre	1 0	1 0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1 8 × °C)+32	(°F−32)/1 8

FOREWORD

The investigation of water use practices in the Imperial Irrigation District was made pursuant to Water Code Section 275 in response to allegations made by a private citizen--John J. Elmore--that the District follows "wasteful and unreasonable policies and practices" in the distribution of water for irrigating crops in that important agricultural area.

In carrying out our assignment, we examined each of Mr. Elmore's charges and compared the "policies and practices" of Imperial Irrigation District with those of similar water agencies elsewhere in the State.

We found that, although the operations of the District are improving, there is water in Imperial Valley now being wasted, which could be saved for beneficial uses.

Jack J. Coe

Jack J. Coe, Chief
Southern District

TABLE OF CONTENTS

APPENDIXES

FIGURES

TABLES

Page

APPENDIXES

FIGURES

TABLES

'VER PHOTO--A concrete-lined District irrigation canal (lateral), near Holtville. DWR Photo 5715-4.

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Lee Hermsmeier, U. S. Department of Agriculture, Imperial Valley Conservation Research Center, Brawley

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Frank Robinson, University of California Meloland Field Station

Douglas Welch, formerly with Soil Conservation Service, El Centro Office

And the many other persons connected with both public and private agencies in the Imperial Valley who gave assistance.

The Department especially appreciates the cooperation it received from the administrative staff of the Imperial Irrigation District who provided many of the data contained in the report.

I. INTRODUCTION

n 1979, the Imperial Irrigation District onveyed more than 3.4 million cubic ekametres (2.8 million acre-feet) of ter from the Colorado River for rigation of desert lands in Imperial lley. Inflow to the Salton Sea from e Imperial Valley in that year was proximately 1.3 million cubic kametres (1.1 million acre-feet), most f it resulting from irrigation in the alley. The level of the Sea has risen bout 1.0 metre (3.1 feet) since 1975, nundating residential and commercial horeline property, farmland, a wildlife efuge, and a State park.

Request for Investigation

his report presents findings regarding pportunities for agricultural water avi s in the Imperial Valley. The indings resulted from an investigation ndertaken, pursuant to Water Code ection 275, at the request of John J. Elmore who, on June 17, 1980, filed an 'Application for Department Investigation f Misuse of Water by the Imperial rrigation District". Elmore has armland adjacent to the Salton Sea.

n his application for the investigation, lmore states: ". . . the level of the alton Sea has been rising over the past ears . . . This rise in height is aving serious adverse consequences for e. It has been necessary, at great xpense, for me to dike much of my armland in order to avoid submergence f my property."

Article 10, Section 2 of the California onstitution states in part:

> "It is hereby declared that because of the conditions prevailing in this State the general welfare equires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare."

This constitutional provision is repeated in Water Code Section 100 and implemented by specific directive to the Department of Water Resources and State Water Resources Control Board in Section 275 of the Water Code. Water Code Section 275 provides:

> "The Department [of Water Resources] and [State Water Resources Control] Board shall take all appropriate proceedings or actions before executive, legislative, or judicial agencies to prevent waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water in this State."

The Department and the Board have adopted regulations in Title 23, California Administrative Code, Chapter 5, Sections 4000-4007, as a basis for administering these provisions quoted above. Section 4001(a) of these regulations states:

> "4001. Investigations. (a) Upon request of the Board, or upon its own motion, or upon good cause shown by any interested person, and in furtherance of Water Code Sections 100, 101, 275, 304 and 305, the Department shall investigate any misuse of water."

The Department and the Board have the responsibility under the above quoted Constitution and Code sections and regulations to investigate claims of waste in the State. The Department has investigated John J. Elmore's allegations against the Imperial Irrigation District and presents in this report the facts gathered during the investigation.

Scope of Investigation

The scope of the investigation has been limited to the collection of data on the allegations against Imperial Irrigation District and to the identification and analysis of the opportunities for conservation of water presently being lost and the potential benefits of such savings. Data used in this report were obtained from published sources, memoranda, field observations, and personal interviews.

Specific allegations explored in this investigation include the following items quoted from Elmore's application of June 17, 1980:

> "I believe the Imperial Irrigation District misuses water through its wasteful and unreasonable policies and practices which apparently include:
>
> "1. Maintaining canals in overly full conditions . . .
>
> "2. Absence of reservoirs for regulation of canal flows . . .
>
> "3. Excess water is often delivered to farmers' headgates resulting in excess tail water run-off from irrigated fields . . .
>
> "4. Absence of tail water recovery systems . . .
>
> "5. Water must be ordered in 24 hour delivery intervals. The delivery cannot reasonably be terminated after the farmer receives sufficient amounts of water . . ."

A copy of the Elmore application is in Appendix A.

Discussions of other opportunities to save water identified during this study, in addition to those related to the Elmore allegations, are also presented in this report.

Conduct of Investigation

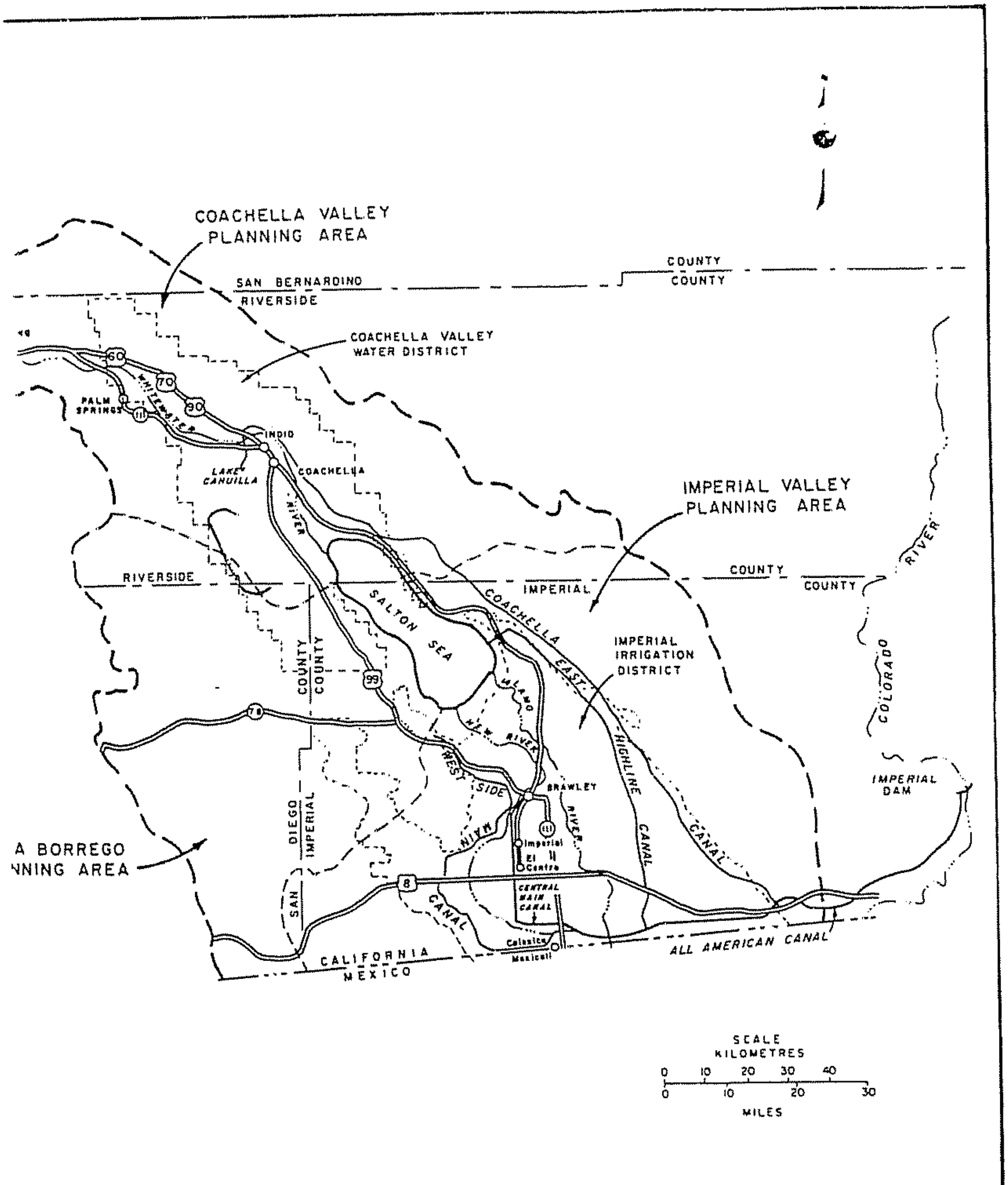
Investigation of the allegations required contacting numerous public and private organizations and individuals. A list of organizations and individuals contacted is shown in Appendix B.

Literature was searched to obtain information on water conveyance, storage, use, and disposal in the Imperial Valley, and in similar areas of irrigated agriculture that would be useful in assessing irrigation practices in the Valley. A list of references appears in Appendix C.

Department personnel made visits to the Valley, observing the actual operations of the District and farmers irrigating their lands. Staff of the District assisted in some of the field reviews. John and Stephen Elmore and District personnel accompanied Department staff on one occasion which included an inspection of the District's facilities and Elmore's farmland, including his levees at the Salton Sea.

Area of Investigation

The area of investigation is the Imperial Valley, the southern part of the Salton Sea Basin, as shown on Figure 1. The basin is the drainage



ure 1 – LOCATION OF THE IMPERIAL IRRIGATION DISTRICT IN RELATION TO THE COACHELLA AND IMPERIAL VALLEYS

RTMENT OF WATER RESOURCES SOUTHERN DISTRICT. 1981

TABLE 1
SALTON SEA INFLOW AND OUTFLOW
In thousand acre-feet*

Year	** Volume	Change in storage	Outflow (evaporation)**	Inflow***						
				Total	Precipitation	Alamo River	New River	Whitewater River	Estimated direct drainage from District	Estimated subsurface and small streams
1965	6,040	- 35	1,260	1,225	12	535	358	88	92	140
66	6,052	+ 12	1,299	1,311	62	611	383	79	106	70
67	6,098	+ 46	1,333	1,379	48	621	383	79	108	140
68	6,080	- 18	1,410	1,392	81	611	384	80	106	130
69	6,052	- 28	1,390	1,362	36	593	375	88	102	168
1970	6,063	+ 11	1,280	1,291	62	619	390	76	108	36
71	6,160	+ 97	1,254	1,351	52	672	423	80	117	7
72	6,202	+ 92	1,275	1,367	5	638	418	91	112	103
73	6,226	+ 24	1,338	1,362	41	639	429	96	113	44
74	6,342	+116	1,422	1,538	29	682	437	91	118	181
1975	6,483	+141	1,370	1,511	31	682	435	98	127	138
76	6,791	+308	1,319	1,627	85	639	435	110	115	243
77	6,910	+119	1,459	1,578	90	616	413	94	109	256
78	6,934	+ 24	1,600	1,624	29	603	393	92	106	401
79	7,030	+ 96	1,402	1,498	77	635	458	95	112	121
1980	7,151	+121	1,420	1,541	83	640	455	83	112	168

* Acre-feet x 1.2335 = cubic dekametres.

** Volume is as of end of calendar year. Outflow (evaporation) for 1965-71 from "Salton Sea Project, Federal-State Feasibility Report", April 1974; for 1979 and 1980 based on long-term unit evaporation; evaporation pan data not yet available.

*** Computed total inflow = outflow (evaporation) ± change in storage.
Precipitation computed from records at U. S. Weather Bureau Station "Brawley" x area of Sea.
Alamo, New, and Whitewater Rivers from USGS Water-Data Reports, except 1980 for Whitewater River is estimated.
Whitewater River for 1979 is for water year. Flows in New and Alamo Rivers include those from Mexico.
Unmeasured direct drainage from District is percentage of District deliveries to farms not drained by New and Alamo Rivers, but that for 1980 is the 1969-79 average.
Subsurface and small streams value is computed (total inflow minus other five inflow items). It includes accumulated errors.

tributary to the Salton Sea.
:asin encompasses about
.:0 ~quare kilometres (8,360 square
es) . the southeastern corner of
:ifornia and extends into Mexico.

t of the Imperial Valley is below
an level, with a minimum elevation
69 metres (227 feet) below ocean
el at the Salton Sea. Two rivers,
New and Alamo, traverse the
ley from Mexico to the Sea.

Salton Sea, a natural sump, is
tained mostly from return irrigation
ws from Imperial and Coachella
leys. Table 1 shows the inflow,
flow (evaporation), and change in
rage relationships for the period
5 through 1980. Direct drainage to
Salton Sea is calculated in Table 2.
:age annual precipitation on the
is 71 millimetres (2.8 inches), and
oration is 1 800 millimetres
inches) per year. Subsurface inflow
been estimated to be about
)0 cubic dekametres (50,000 acre-
per year. The Sea, in 1981, had
urfa area of about 987 square
ometres (381 square miles) and an
:age surface elevation of -69 metres
27 feet). During the 12 months
ing March 1, 1981, the Sea rose
3 metre (0.1 foot). Periods of
ense rainfall can cause temporary
:eases in the Sea's surface elevation
as much as 244 millimetres (0.8 foot),
was the case with tropical storm
leen in 1976.

salinity of the Sea, measured in
s of total dissolved solids (TDS)
:ent, was 38 800 milligrams per
e (mg/L) in September 1981. The
concentration of water in the New
Alamo Rivers as they entered the
was in the range of 3 200 to
)0 mg/L.

Imperial Irrigation District has
rea of 430 000 hectares (1,062,900
:s). About 45 percent of the District is devoted to irrigated agriculture. In 1979, 186 000 hectares (460,000 acres) were irrigated and about 6 500 hectares (16,000 acres) were devoted to urban land uses. Major crops are alfalfa, wheat, cotton, and lettuce. The population in the Valley is about 94,500, mostly concentrated at El Centro, Brawley, and Calexico.

With very low annual precipitation in the Imperial Valley, the main source of water for the Valley is the Colorado River. The All-American Canal is the link between the Colorado River and the distribution canals that crisscross the Imperial Irrigation District. Colorado River water is used for both irrigation and urban uses. The District also operates a system of drainage ditches that convey tailwater, tile drain water, unused Colorado River water, and storm water runoff to the Salton Sea.

There is ground water throughout the District at shallow depths. It is sustained primarily from percolation of applied irrigation water, and its surface level is controlled by drains. Because of high salt content, it is not used.

The ground water underlying irrigated lands within the Imperial Irrigation District is generally of three types at three depth ranges: (1) a shallow unconfined perched ground water that is generally tile-drained at 1.8- to 2.4-metre (6- to 8-foot) depths, but ranges to depths of 12 metres (40 feet) below ground surface. The salinity varies, generally within a range of 2 500 to 4 500 mg/L, based on the TDS content of tile-drained water. Since much of this area is underlain by lake deposits which have a relatively low permeability, it would be difficult to extract this ground water from shallow wells; (2) an intermediate to deep ground water reservoir, which Loeltz, et al. in 1975* found to be ". . . underlain by great thicknesses

complete list of references cited is given in Appendix C.

TABLE 2
IMPERIAL VALLEY COMPONENT DRAINAGE TO THE SALTON SEA
In thousand acre-feet*

	District deliveries to farms			Measured drainage from					Percent of deliveries drained by rivers***	Drainage to Sea	
				Mexico via		Imperial Valley via					
Year	Total (1)	Drained by New and Alamo Rivers** (2)	Draining direct to Sea** (3)	Alamo River (4)	New River (5)	Alamo River (6)	New River (7)	Both Rivers† (8)	(8)÷(2)x100 (9)	Direct (3)x(9) (10)	Total† (8)+(10) (11)
1965	2312	2067	245	1.8	111.5	533	246.5	779.5	37.7%	92	871.5
66	2470	2208	262	1.5	102.5	609.5	286	895.5	40.6%	106	1001.5
67	2365	2174	258	1.6	96.9	619.5	291	910.5	41.9%	108	1018.5
68	2476	2243	266	1.5	106.0	609.5	278	887.5	39.6%	106	993.5
69	2352	2103	249	1.6	103.3	591	272.5	863.5	41.1%	102	965.5
70	2418	2162	256	1.6	99.7	617.5	291	908.5	42.0%	108	1016.5
71	2535	2266	269	1.5	107.3	670	316	986	43.5%	117	1103
72	2531	2263	268	1.4	111.1	637.5	307	944.5	41.7%	112	1056.5
73	2670	2387	283	1.4	117.2	637.5	311.5	949	39.8%	113	1062
74	2777	2483	294	1.2	111.8	681.5	319	1000.5	40.3%	118	1118.5
75	2704	2417	287	1.6	49.8	681	384	1065.5	44.1%	127	1192.5
76	2515	2248	267	1.1	102.9	638	332	970	43.1%	115	1085
77	2455	2195	260	1.4	107.7	613.5	306	919.5	41.9%	109	1028.5
78	2441	2182	259	1.3	98.4	602	294	896	41.1%	106	1002
79	2571	2298	273	1.1	144.9	633	312.5	945.5	41.2%	112	1057.5

* 1 acre-foot = 1.2335 cubic dekametres.
** 89.4 percent of District irrigated acreage is drained by the New and Alamo Rivers; 10.6 percent drains directly to the Salton Sea. Deliveries assumed to be generally uniformally distributed throughout the service area.
*** These percentages also equal the percentage of total deliveries (Column 1) draining to Sea.
† Excluding Mexican water.

of water-saturated lacustrine and playa deposits . . ." that generally hav ow vertical permeability. East of the Alamo River, ground water is artesian and has a TDS content ranging from about 700 to 5 700 mg/L, with most concentrations between 1 000 and 2 000 mg/L. The ground water from artesian wells is generally warm and may contain high concentrations of boron, fluoride, and chloride; and (3) deeper geothermal waters, varying in depth from 900 to 1 500 metres (3,000 to 5,000 feet). These waters may be superheated and supersaturated, containing TDS concentrations of as much as 350 000 mg/L. However, generally they increase from 25 000 near Heber to 250 000 mg/L toward the Salton Sea.

II. IMPERIAL IRRIGATION DISTRICT

The California Development Company was formed in 1896 to reclaim Imperial Valley with Colorado River water. A canal was excavated by the Company connecting the Colorado River with the Alamo River, which then was used as an unlined canal. In 1905, the Colorado River during flood stage broke through into the Imperial Valley and continued unchecked until February 1907. The result was the restoration of the Salton Sea. The financial burden imposed on the Company by the flood and closing off the break in the River caused it to go into receivership.

The Imperial Irrigation District was formed in 1911 under the California Irrigation District Act. In 1916, the District became the holder of rights to Colorado River water formerly held by the California Development Company. Its primary function was to provide irrigation water to the farmers.

The District was at first only a purveyor of water; however, later the District began producing and selling electrical power.

The District is governed by a Board of Directors. The five directors are elected by registered voters residing in the District.

Water Rights and Contracts

Rights to divert water from the Colorado River have been established through years of negotiations and litigation. The first Colorado River water was diverted into Imperial Valley in 1901. The original water rights were acquired by individuals who later assigned their rights to the California Development Company. The Company rights were then acquired by the District in 1916.

The most significant documents that relate to the California and District water supply from the River are summarized as follows:

Colorado River Compact

The Compact was signed by representatives of the seven Colorado River Basin states in 1922. It divides the water of the River between the Upper and Lower Basins at Lee Ferry, Arizona.

Boulder Canyon Project Act

The Boulder Canyon Project Act of 1928 approved the Colorado River Compact and authorized construction of Hoover Dam and Powerplant and the All-American Canal. It also required California to adopt legislation limiting its use of Colorado River water before the Act would take effect.

California Limitation Act

The California Limitation Act was enacted by the State Legislature in 1929 as required by the Boulder Canyon Project Act. It limited California's consumptive use to 5.4 million cubic dekametres (4.4 million acre-feet) of the first 9.2 million cubic dekametres (7.5 million acre-feet) apportioned to the Lower Basin plus not more than one-half of any surplus waters.

Seven-Party Water Agreement

The Seven-Party Water Agreement was entered into by the California parties in 1931 in response to a request by the Secretary of the Interior for a priority agreement in California. In recognition of the ongoing use and early filings by agricultural users, they were given first priorities to water. A listing of the priorities in

TABLE 3
LISTING OF PRIORITIES--SEVEN-PARTY AGREEMENT

Agency and description of service area	Beneficial consumptive use, in acre-feet/year*
Palo Verde Irrigation District--104,500 acres in and adjoining existing district.	
Yuma Project, California Portion, not exceeding 25,000 acres.	3,850,000
(a) Imperial Irrigation District and other lands that will be served from the All-American Canal in Imperial and Coachella Valleys.	
(b) Palo Verde Irrigation District--16,000 acres of adjoining mesa.	
The Metropolitan Water District of Southern California and cities on the coastal plain.	550,000
(a) The Metropolitan Water District of Southern California and cities on coastal plain.	550,000
(b) City and/or County of San Diego.	112,000
(a) Imperial Irrigation District and other lands that will be served from the All-American Canal in Imperial and Coachella Valleys.	300,000
(b) Palo Verde Irrigation District--16,000 acres of adjoining mesa.	
	5,362,000

feet x 1.2335 = cubic dekametres.

eement is shown in Table 3.

ɛrican Canal Agreement

ng the Boulder Canyon Project e District and Department of the r consummated the All-American greement in 1932.

States Supreme Court Decree

ted States Supreme Court decree in 1964 guaranteed California's rights to 5 430 000 cubic dekametres (4,400,000 acre-feet) per year.

Enforcement of this limitation will commence with initiation of diversions for the Central Arizona Project. This limitation did not affect water allocated in the first three priorities of the 1931 Agreement, totaling 4 750 000 cubic dekametres (3,850,000 acre-feet) per year.

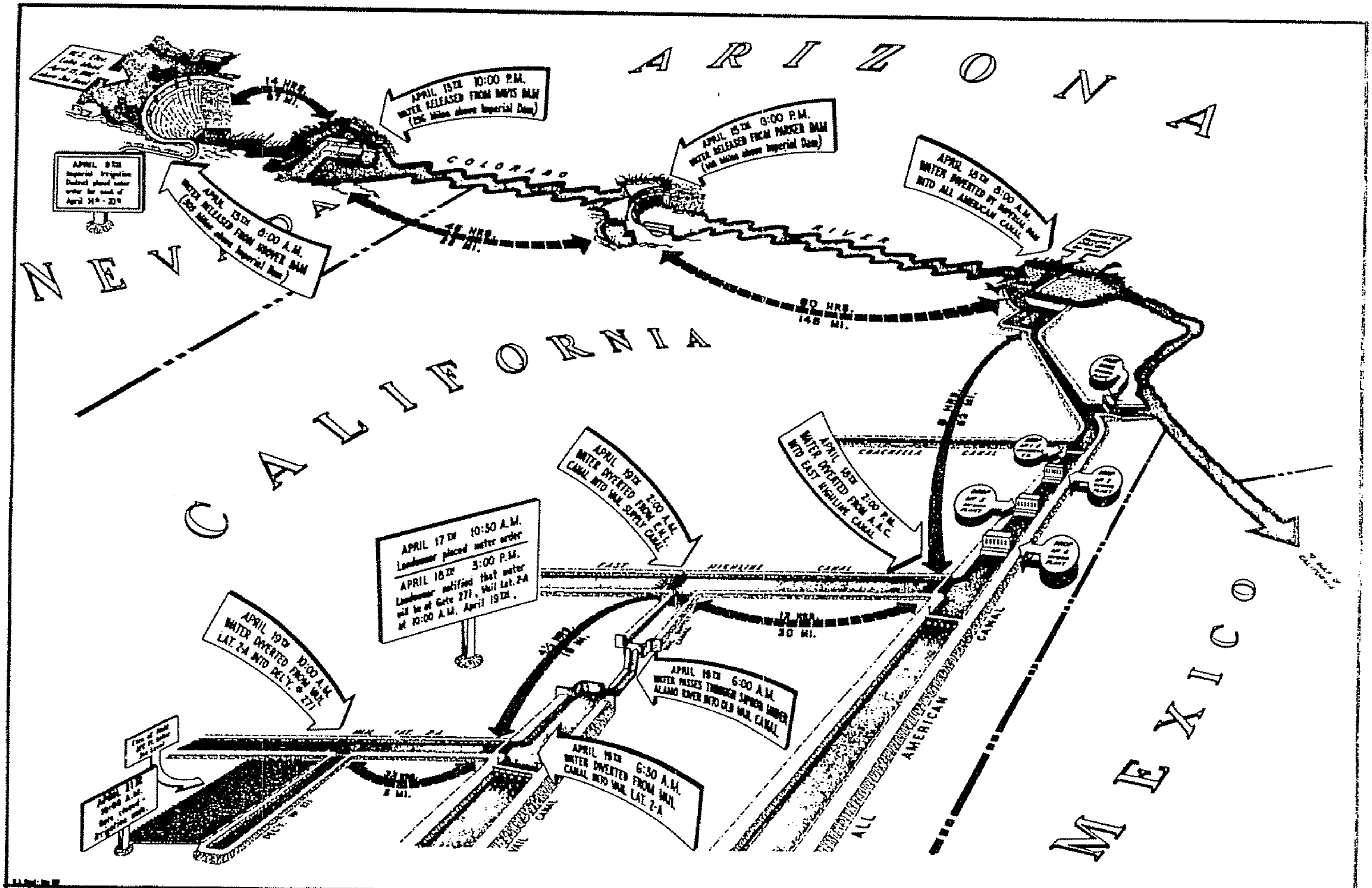


FIGURE 2- IMPERIAL IRRIGATION DISTRICT
WATER TRANSPORTATION
HOOVER DAM TO USER

District, which receives most of its : under Priority 3, has a present ect right to 3 207 000 cubic etres (2,600,000 acre-feet) of the 000 cubic dekametres that is ornia's apportionment of Colorado water (Colorado River Board of ornia, 1979). This is approximately)00 cubic dekametres (300,000 acre-) less than the average diversion ged to the District at Imperial Dam 247 000 cubic dekametres 000 acre-feet) less than that ing the District's service area op 1 for 1975-79.

the commencement of diversions e Central Arizona Project, ultural diversions to California be reduced to 4 750 000 cubic etres (3,850,000 acre-feet). ultural diversions under the Seven-: Agreement are about 5 120 000 cubic etres (4,150,000 acre-feet). The ions to the future agricultural ion amount will be made in iance with the priorities shown able 3.

Conveyance Facilities

All-American Canal system consists perial Dam, All-American Canal works and desilting basins, All-can Canal, Coachella Canal, and tenant structures. The locations he All-American Canal, Coachella l, and other main canals are shown igure 1.

ial Dam, headworks, and desilting s can supply 430 cubic metres 00 cubic feet) per second of water e All-American Canal. The entire ery system is operated through ty flow. The District has ructed four hydroelectric power s to take advantage of drops in tion along the All-American Canal. wer plants are located at Pilot Check and at Drops 2, 3, and 4. ndbreaking ceremony was held on 9, 1981, to start construction e D 5 power plant.

The District's gross orders for diversion at Imperial Dam include requirements for the Yuma Project adjacent to the Colorado River, Imperial and Coachella Valleys, and, at times, Treaty (U. S. Congress, Senate, 1944-45) water for Mexico, which is carried in the All-American Canal and returned to the river through the Pilot Knob Hydroelectric Plant.

The District operates and maintains 2 830 kilometres (1,760 miles) of conveyance and distribution facilities. The main facilities are the 129-kilometre (80-mile) long All-American Canal, which terminates west of Calexico, and its branches, listed from east to west, which carry water north: the Coachella Canal (the Coachella Valley Water District took over total operation in November 1980), the East Highline Canal, the Central Main Canal, the Westside Main Canal, and the smaller lateral canals. The District also operates and maintains 2 330 kilometres (1,450 miles) of drains to collect irrigation return flows (tailwater and tile drain flows).

The District has constructed two regulating reservoirs, within the distribution canal network, in the Imperial Valley. The Kakoo Singh Reservoir was completed in 1976 and another, the J. M. Sheldon Reservoir, in 1977. These reservoirs have storage capacities of 395 cubic dekametres (320 acre-feet) and 740 cubic dekametres (600 acre-feet), respectively.

Operations

Scheduling and Deliveries

The District orders water from the U. S. Department of the Interior at Imperial Dam for the about 5,500 farm headgates it services. It must place its order 6 to 11 days in advance of the time water is to be delivered at the headgates. This is shown graphically on Figure 2.

Farmers place their water orders with the District at least 24 hours, but generally between 48 and 72 hours, in advance of their needs. Hydrographers in the water control section of the District, under the supervision of the District Watermaster, are responsible for the distribution of water into the main and lateral canal systems to meet the accumulated needs of the farmers served from them. Water is delivered on a continuous flow basis with flow changes normally made once per day. The delivery points (farmers' headgates) serve farmlands which range in size from 8 to 130 hectares (20 to 320 acres). Orders for water generally range between 0.1 and 0.4 cubic metre (4 and 15 cubic feet) per second. The price of water delivered to the farmer is $6.08* per cubic dekametre ($7.50 per acre-foot).

The District intends to raise this to $6.90 per cubic dekametre ($8.50 per acre-foot) on January 1, 1982. Revenue from the increased rate as of July 1, 1981, is exclusively directed toward water conservation activities.

The District normally releases more water than is ordered to offset losses in the distribution system, thus ensuring that the farmer will receive a full order.

Zanjeros (canal headgate tenders) are in charge of opening and closing the farmers' headgates in the lateral canals. They start water deliveries early in the morning and return in the afternoon to adjust headgates to maintain proper flows. The ability of the District to take back excess water when a farmer orders too much depends on the type of delivery operation, the location of the field, and the requests by other farmers who may want to take the excess water.

In 1979, the District diverted water from the Colorado River to irrigate 233 000 hectares (576,000 acres) of crops (including multiple cropping) in the Imperial Valley and 26 700 hectares (66,000 acres) in the Coachella Valley plus land in the Yuma Project. Also, water was diverted for municipal and industrial uses in Imperial Valley (about 30 800 cubic dekametres, or 25,000 acre-feet). Table 4 shows operational data for water received at Drop 1 on the All-American Canal for the years 1955-79.

Figure 3 was derived by using an average of 5 years (1975-79) of water flow data from Tables 2 and 4. Approximately 34 percent of the water delivered to the users passes on to the Salton Sea. Figure 4 shows how the quantity of water delivered decreases through various measuring points in the system.

Monitoring and Control System

The flow in the canals is regulated by gate structures strategically placed throughout the system. These gates are opened or closed as necessary to pass the proper amount of water from one part of the system to the next. The water surface in each reach of canal is maintained relatively constant near the top of the canal to reduce the start-up or shut-down time in changing flow rates and to reduce erosion damages along the unlined canal banks. The actual flow rate is regulated by the degree of opening of the gates and is not as much affected by the depth of water in the canal.

There are about 492 control gates in the canal system. These gates are operated by the District water control section hydrographers under the supervision of the Watermaster.

In an effort to improve operations and reduce losses, the District, in March 1957, installed the first telemetering

* Increased from $5.27 per cubic dekametre ($6.50 per acre-foot), effective July 1, 1981.

TABLE 4
IMPERIAL IRRIGATION DISTRICT CONVEYANCE SYSTEM EFFICIENCIES, 1955-79
In thousand cubic dekametres
(thousand acre-feet)

r	Water received by District at Drop 1		Total deliveries* to users		Operational losses**		Conveyance system efficiency (%)
5	3610	(2,927)	2419	(1,961)	1191	(966)	67.0 %
56	3586	(2,907)	2482	(2,012)	1104	(895)	69.2 %
7	3431	(2,782)	2404	(1,949)	1027	(833)	70.1 %
8	3369	(2,731)	2394	(1,941)	975	(790)	71.1 %
9	3503	(2,840)	2522	(2,045)	981	(795)	72.0 %
0	3681	(2,984)	2687	(2,178)	994	(806)	73.0 %
1	3647	(2,957)	2709	(2,196)	938	(761)	74.2 %
2	3640	(2,951)	2743	(2,224)	897	(727)	75.4 %
3	3689	(2,991)	2819	(2,285)	870	(706)	76.4 %
4	3417	(2,770)	2959	(2,399)***	458	(371)	86.6 %***
5	3237	(2,624)	2852	(2,312)	385	(312)	88.1 %
6	3476	(2,818)	3047	(2,470)	429	(348)	87.7 %
7	3355	(2,720)	2917	(2,365)	438	(355)	87.0 %
8	3461	(2,806)	3054	(2,476)	407	(330)	88.2 %
9	3301	(2,676)	2901	(2,352)	400	(324)	87.9 %
0	3398	(2,755)	2983	(2,418)	415	(337)	87.8 %
1	3557	(2,884)	3127	(2,535)	430	(349)	87.9 %
2	3512	(2,847)	3122	(2,531)	390	(316)	88.9 %
3	3646	(2,956)	3293	(2,670)	353	(286)	90.3 %
4	3789	(3,072)	3425	(2,777)	364	(295)	90.4 %
5	3702	(3,001)	3335	(2,704)	367	(297)	90.1 %
6	3434	(2,784)	3102	(2,515)	332	(269)	90.3 %
7	3322	(2,693)	3028	(2,455)	294	(238)	91.2 %
8	3296	(2,672)	3011	(2,441)	285	(231)	91.3 %
9	3457	(2,803)	3171	(2,571)	286	(232)	91.7 %

RCE: Imperial Irrigation District, Annual Summary, Water Diversion, Transportation, Distribution and Drainage, United States and Mexico, 1955-79.

This is water released to canals adjacent to farmers' headgates for subsequent delivery through the headgates. Portions of this water which are rejected by farmers and not diverted to others as a supplemental delivery may spill at the end of the canal. This type of loss (included here as part of "Deliveries") has been approximated at 1 to 2 percent of the "delivery" amount (J. R. Wilson telephone interview March 26, 1981).

Operational losses include evaporation, seepage, leakage, and approximately 1600 minor service pipes which are unmeasured.

In 1964, the District changed calibration on the flow measurements to water users by 10 percent.

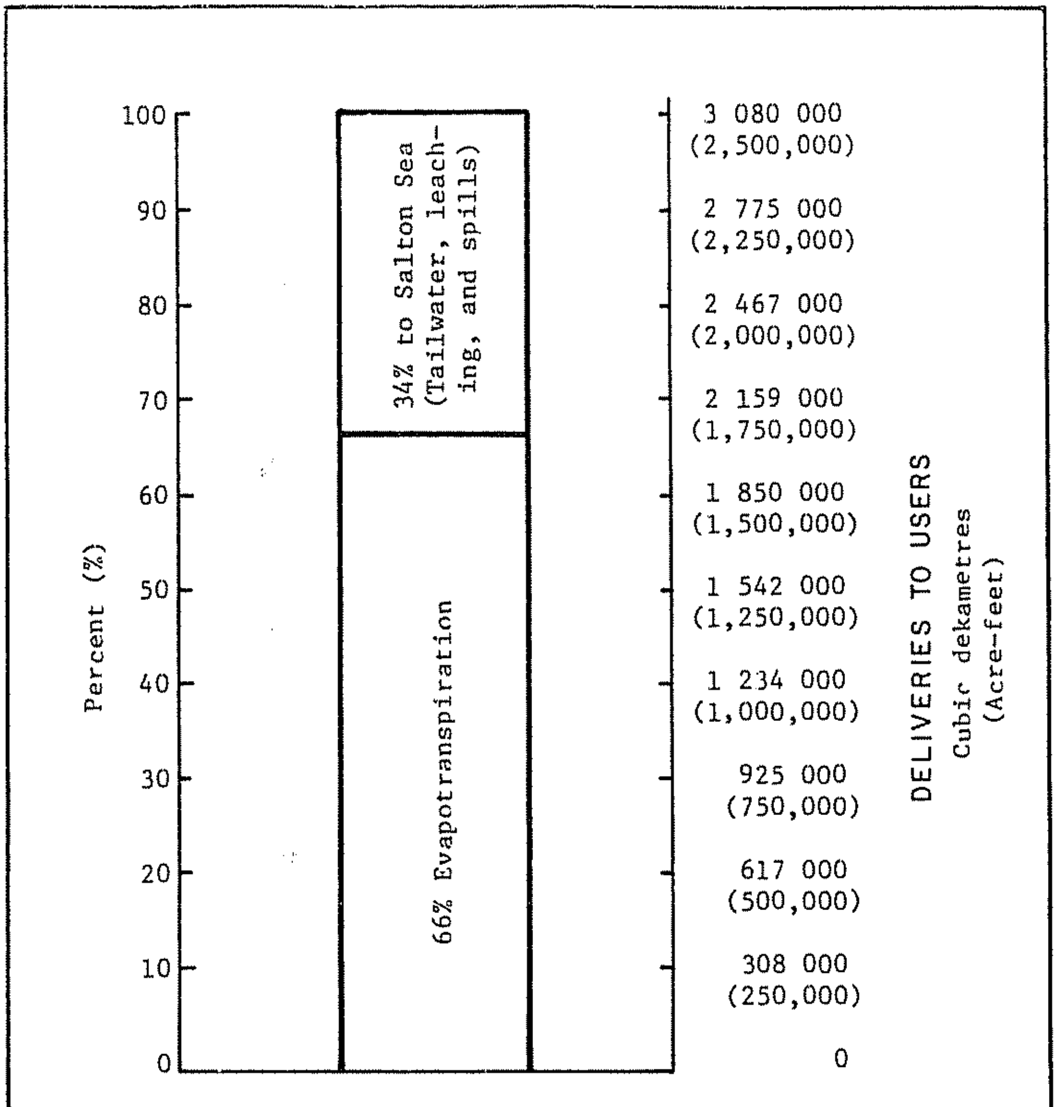


FIGURE 3 - WATER DELIVERED TO USERS, PERCENTAGE TO SALTON SEA AND EVAPOTRANSPIRATION, IMPERIAL IRRIGATION DISTRICT (Average for 1975-79)

unit at the Nectarine (Vail) Check on the East Highline Canal, permitting monitoring and operation of diversion gates to the Vail Canal from the Watermaster's office at Imperial, a distance of approximately 33.8 kilometres (21 miles). Since that date, remote electronic monitoring and control devices have been installed at 19 other locations, including the All-American Canal. Data on the flows which have been carried in the canals, as well as flows to various points in the drains, are collected and kept on file by the District.

District Conservation Programs

The District is involved in a program to improve unit irrigation efficiency and achieve water conservation. A Citizens' Committee was formed early in

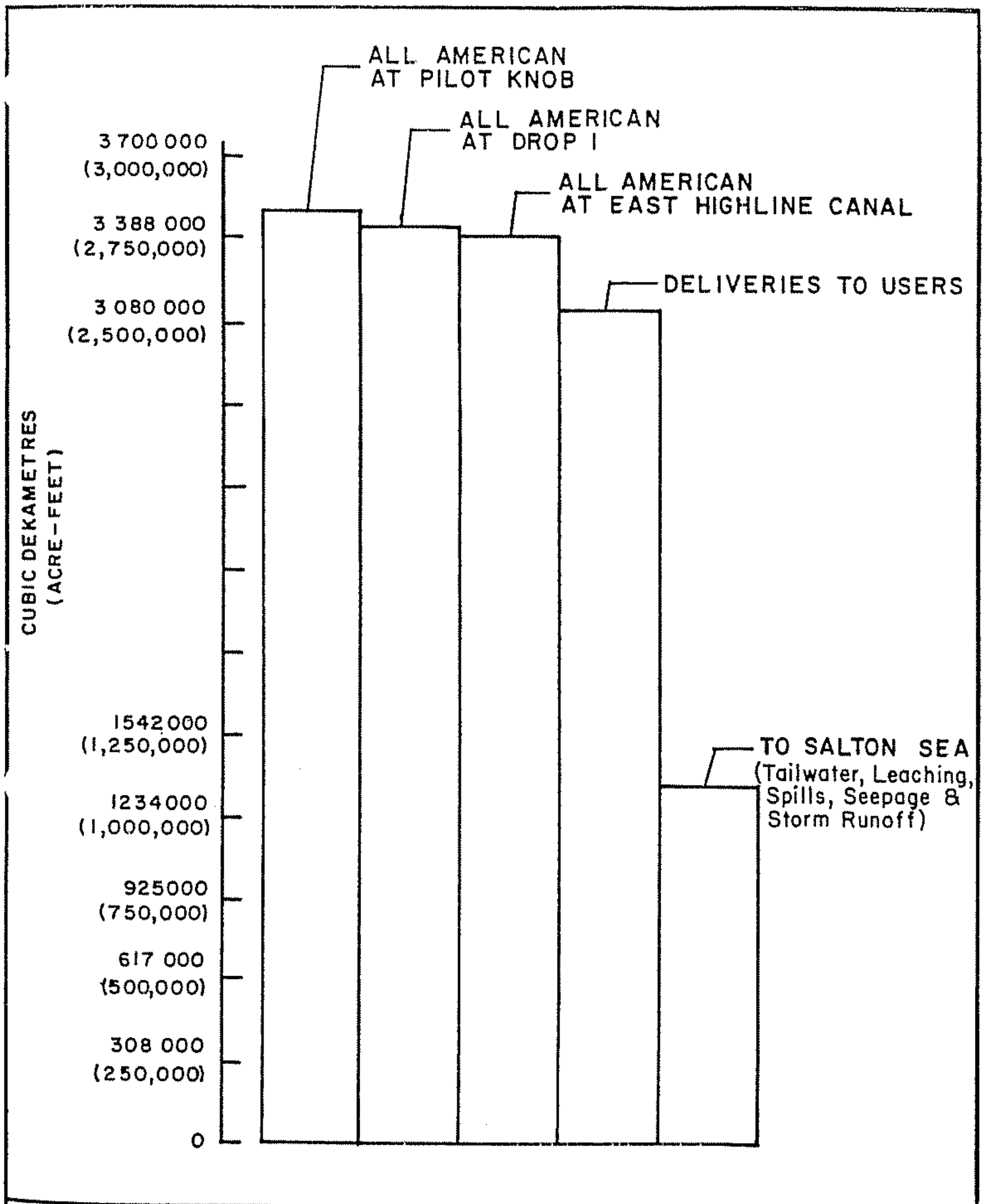


FIGURE 4 - DELIVERED WATER AND DRAINAGE TO SALTON SEA

6 to study problems related to icultural drainage into the Salton Sea ıp. The committee's recommendations e pr -ented to the Board and incorporated in a 13-Point Conservation Program.

The District and the U. S. Department of

DEFINITIONS

Evapotranspiration (ET): the quantity of water transpired by plants, retained in plant tissue, and evaporated from adjacent soil surfaces in a specific time period. Usually expressed in depth of water per unit area. As used here, ET is synonymous with consumptive use.

Conveyance system efficiency: the ratio of the volume of water delivered to users to the volume of water introduced into the conveyance system. The conveyance system for the Imperial Irrigation District service area starts at Drop 1 on the All-American Canal.

Irrigation efficiency: the ratio of the volume of water used for ET in cropped areas to the volume of water delivered for that purpose (applied water).

District irrigation efficiency: the ratio of the volume of water used for ET in cropped areas to the volume of water delivered to all farms (applied water) in an irrigation district service area.

Unit irrigation efficiency: the ratio of the volume of water used for ET in cropped areas, plus that amount necessary to maintain a favorable salt balance in the soil (leaching fraction), to the volume of water delivered for these purposes (applied water). In this report, the unit irrigation efficiency has been estimated on a districtwide basis.

(Sources: California Department of Water Resources, Vegetative Water Use in California, 1974, April 1975; Hagan, R. M., Haise, H. R., and Edminster, T. W., Irrigation of Agricultural Lands, American Society of Agronomy, 1967; and Jensen, M. E., ed., Consumptive Use of Water and Water Requirements, American Society of Civil Engineers, 1973.)

Agriculture, Imperial Valley Conservation Research Center, Brawley, are conducting a cooperative study to evaluate unit irrigation efficiency under conventional soil and water management and the effect and applicability of new soil and water management practices designed to improve unit irrigation efficiency.

Late in 1979, a new Water Conservation Advisory Board was formed by the District Board of Directors. This Board of 10 farmers and 5 District representatives, after outlining about 10 major problems, adopted a resolution containing 21 recommendations which the District Board of Directors adopted on June 24, 1980.

The 13-Point Conservation Program, the 21-Point Water Conservation Program, and the By-Laws of the District Water Conservation Advisory Board are presented in Appendix D. One of the major programs is the lining of canals, both District-owned and farmer-owned. It has been proposed that the All-American Canal be lined either partly or wholly (U. S. Congress, House, Committee on Interior and Insular Affairs, 1967).

The District has studied the use of regulating reservoirs as a means of reducing loss of water and improving operating characteristics of its system. Studies indicate that as many as 16 rvoirs could be used to control all water in the canals. Two reservoirs be constructed and are in ation. Land has been purchased and truction of a third reservoir is in ress. Other regulating reservoirs under consideration while the rict evaluates the cost effectiveness he existing reservoirs.

ional automation of the control ctures in canals has been studied means of providing better control ater movement and saving water.

art of the 21-Point Water ervation Program, the District has loped rules and regulations to ove management of its water supply. e rules and regulations also enhance r conservation. One important lation is the penalty assessment ed on farmers who have tailwater s in excess of 15 percent of water vered to their headgates.

Other Studies of District Operations

J. S. Department of the Interior Bureau of Reclamation (USBR) is currently conducting a comprehensive investigation of the water conservation opportunities which exist within the Imperial Irrigation District. The study commenced in 1980 and is designed to be completed by September 1983. The activities include developing guidelines for improved conveyance system, District irrigation, and unit irrigation efficiencies, especially related to regulatory reservoir construction, system automation, canal lining, on-farm management, and collection and reuse of waste water.

An earlier preliminary study by USBR, conducted in 1977 and 1978 (USBR and BIA, 1978), cited the District as having a potential to reduce Colorado River diversions by 432 000 cubic dekametres (350,000 acre-feet). The areas of improvement which would result in reduced diversions were identified as: lining of the main canals (except the All-American Canal), lining of District laterals, lining of on-farm ditches, reorienting and leveling fields, and providing an irrigation scheduling program.

III. DISCUSSION OF JOHN J. ELMORE'S ALLEGATIONS OF MISUSE OF WATER

This chapter addresses the Elmore allegations as quoted below and describes the physical situation in respect to each case and the opportunities for water savings of each.

Allegations by John J. Elmore

John J. Elmore's allegations:

> "I believe the Imperial Irrigation District misuses water through its wasteful and unreasonable policies and practices which apparently include:
>
> "1. Maintaining canals in overly full conditions. In order to provide 'quick' delivery service of irrigation water, canals are kept overly full to such an extent that overflow gates at the terminal ends of the canals are frequently spilled over. The use of the canals as 'reservoirs' is inappropriate in light of the significant amount of spillage and waste.
>
> "2. Absence of reservoirs for regulation of canal flows. The absence of reservoirs causes unnecessary delivery of excess amounts of water producing spillovers and run-offs into the Salton Sea.
>
> "3. Excess water is often delivered to farmers' headgates resulting in excess tail water run-off from irrigated fields. Water should not be delivered in an amount greater than that actually needed by the farmers. Provisions should be made to divert water to other users when farmers miscalculate the amounts of water they actually need.
>
> "4. Absence of tail water recovery systems. Tail water run-off is currently draining directly into the Sea. Recovery systems would allow the capture of the run-off for productive use.
>
> "5. Water must be ordered in 24 hour delivery intervals. The delivery cannot reasonably be terminated after the farmer receives sufficient amounts of water. Excess water from the 24 hour delivery drains unused into the Salton Sea. Other needy water users are not contacted to use excess water delivered during the required 24 hour period. Therefore, any miscalculations in estimating the amount of water needed by a farmer results in significant waste."

Response by Imperial Irrigation District to John J. Elmore's Allegations

The District responded to Elmore's allegations in a letter to the Department, dated May 12, 1981. This letter, which has been reproduced in its entirety in Appendix E, contains the District's responses to the allegations as follows:

> "As concerns the allegations made by John J. Elmore that Imperial Irrigation District; i.e., the public agency itself, is practicing wasteful water

management and marketing practices in the operation of the water division of this district is simply not so.

"First of all, I think it is important to take into consideration the fact that the District diverts water at Imperial Dam, approximately 60 miles from the system. The quantity ordered at Imperial Dam is released from Parker Dam, some 160 miles upstream, for there is no storage at Imperial Dam. (See Exhibit A attached hereto and made a part hereof).* The operating criteria under which the District performs requires that Imperial Irrigation District place its orders for water on each Wednesday for deliveries to the farmer commencing on Monday through Sunday. Or to put it another way, the District in essence is anticipating what the farmers will require for their operation as much as 11 days in advance, notwithstanding the vagaries of weather such as wind, rain, humidity, or any other variable.

"Furthermore, the District does not dictate to the farmer as concerns the quantity of water ordered. This decision rests solely with the farmer and not with Imperial Irrigation District. If the farmer orders 10 second-feet for 24 hours and only uses 8 second-feet, obviously, the 2 remaining second-feet which cannot be used for a period of time is returned to the District's system.

"While Mr. Elmore alleges that Imperial Irrigation District is diverting canal water to the Salton Sea, the fact of the matter is that the water which finds its way to Salton Sea through the lateral system is water which has been returned unused to the District (often without authorization) by the farmer who has ordered more water than he needs to irrigate his land. While the same is wet water and finds its way to the sea, in actuality it is water which was paid for but not used by the person who ordered the same. This has been a common practice throughout the District's system in recent years.

"The District has tried continuously to encourage the water users to order only water actually needed to irrigate the land properly and not waste the same and/or return any overage to the District's system for there simply is no storage in the District's canal system for this purpose.

"The District, as you well know, has no police power by way of any statute or otherwise so, consequently, when the District seeks to encourage the farmer to use the water wisely and prudently and not waste the same, the task of this undertaking becomes increasingly difficult, if not impossible, for there is no remedy available to us.

"Dealing with the matter of the exhibits to which Mr. Elmore has referred and on which he relies to support his position--Exhibits 1, 2 and 3**--the findings those reports make which deal with the matter of concrete lining are not only

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*Exhibits A, B, and C are contained in Appendix E.
**Exhibits 1, 2, and 3 are contained in Appendix A.

outdated in a rather marked way but do not take into consideration the fact that Imperial Irrigation District has over half of its canal system already concrete lined; all of its regulating structures are in concrete form, including the deliveries which make the diversions possible from the canal system, which required replacement of 5,000 wooden structures in the latter years without governmental assistance of any nature whatsoever. The Department of the Interior, Bureau of Reclamation, has made the statement that they know of no other district in the western hemisphere which has made the progress this district has made in the field of concrete lining.

"Laser beam leveling is not new to this area. As a matter of fact, it has been practiced from time to time but dead-level type design for the types of soils in this area is not a practical solution, in our opinion.

"Leaching and the quantity of water applied to accomplish the objective, as we understand under the formula used, is very, very low compared to other standards in other states. The Colorado River Board of California indicates that the District's application by formula is too low and the figures should be increased to show a more realistic quantity of applied water to the soil profile.

"Dealing with the matter of employing pump-back systems and sprinkler-soaker type irrigation and the lack thereof, according to the report, simply does not tell it like it is. Many of the farmers have gone sprinkler irrigation and have invested large sums of money in doing so. Pump-back systems, in our judgment, are an obligation and concern of the water user and not Imperial Irrigation District, for if the farmer desires to return his tail water--which on many ocassions [sic] is interlaced with nitrate, phosphate, and ammonia, fertilizers, herbicides and other undesirable elements--to the operator's head ditch is acceptable but unacceptable to introduce the same into the District's canal system for the sake of creating a reservoir, for the contaminated water cannot be permitted to enter into the District's canal system simply because the Health and Safety Code prohibits this practice, for the same is used for domestic and industrial purposes.

"There are many discrepancies in the statement made based on today's facts. For one, the bulletin recites that water is being sold for $3.00 an acre-foot, when in reality the charges being assessed today by the District are $6.50 an acre-foot. This is not the only expense the farmer is obligated to pay. He is also required to tile the ground he farms to cope with the high salinity index of the water he receives, for Imperial Irrigation District is located on the tail end of the Colorado River system which necessitates the District to accept all return flow from upstream users, as the Colorado River is the sole and only source of water available to the District.

"The affidavit submitted by William S. Gookin, Consulting Engineer, to which Mr. Elmore refers as Exhibit 3 and upon which he relies, is difficult at best to accept when one compares the document submitted in opposition t reto by Maurice N. Langley, a former long time employee of the U. S. Department of the Interior, Bureau of Reclamation, and a professional Agricultural Engineer in California and Wyoming; a registered Civil Engineer in the District of Columbia; and certified by the American Registry of Certified Professional in Agronomy, Crops and Soils as a Professional Agronomist and Soil Scientist. His resume is attached hereto in affidavit form.* Mr. Langley is presently vice president of Bookman-Edmonston, a water engineering firm dealing with water and water related matters which I think is very well known to those who operate in the west and who are interested in water agricultural problems in the State of California. (Exhibit B)

"Al attached hereto and made part hereof for the purpose of the record is an affidavit executed by J. Robert Wilson. (Exhibit C)

"One other point that we think is important to make reference to is the fact that Mr. Gookin in determining his findings uses 9 sump pumps for his factoring to develop the quality of water, when in reality the District, as of November 1, 1979, was operating 454 like sump pumps in the valley floor and 30 such pumps which surround Salton Sea. The State should review and study this issue, or we believe the affidavit on its face, taking into consideration the information submitted therein, leaves much to be desired."

Considerations in Determining Reasonableness of Water Use

The California Constitution mandates that ". . . the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof . . ."

"Reasonable use" is a common term in laws dealing with water; however, there is no exact definition of "reasonable use". Generally speaking, reasonableness depends on the facts and circumstances of the case. In determining whether unreasonable use of water is occurring, some yardstick, or parameter, must be identified against which the allegation of misuse of water can be measured.

An article appearing in the Agricultural Law Journal (Kramer and Turner, 1980) suggests seven considerations which should be addressed in developing factual information on the reasonableness of a given water use. Not all seven need be addressed in every case; however, these considerations do provide a useful analytical tool. The collection and compilation of facts in this investigation have been guided by these considerations:

"1. The Potential Beneficial Uses of Water Saved"

"In instances where the courts have found a misuse of water, they have generally identified the potential beneficiaries" and uses of any water savings.

"2. Whether the Excess Water Now Serves a Reasonable and Useful Purpose, e.g., Ground Water Recharge"

"The recapture or inadvertent use of waste waters may mitigate the

*Appendix E.

effect of the waste by resulting in a reasonable use of water in the whole area. For example, valuable fish and wildlife habitat could be maintained by the waste of water." Also, percolation of excess irrigation applications could replenish ground water supplies.

"3. <u>The Probable Benefits of Water Savings"</u>

"The economic and environmental benefits that would result" from plans for additional "reasonable use of water should be estimated."

"4. <u>The Amount of Water Reasonably Required for Current Use"</u>

In some instances, "it may be necessary to estimate the duty of water" to establish reasonable water use requirements. In other instances, it may be easier to identify excess water or unreasonable use of water directly.

"5. <u>The Amount and the Reasonableness of the Cost of Saving Water"</u>

"The courts will require one who misuses water to incur additional reasonable inconvenience or expense where this is the only feasible way" to achieve reasonable uses of water.

"6. <u>Whether the Required Methods of Saving Water Are Conventional and Reasonable Practices Rather Than Extraordinary Measures"</u>

Local custom is one test of whether methods of use are reasonable. Court cases have indicated "that a water user is entitled to make reasonable water use according to the custom of the locality and is not bound to adopt the most scientific method known. Therefore, community standards of good practice must be determined. However, local custom is not determinative if the custom itself amounts to a misuse of water."

"7. <u>A Physical Plan or Solution"</u>

This is an important consideration as "many court decisions have indicated that a misuse of water" will be prohibited "where there is a feasible physical plan or solution available."

<u>Consideration of Specific Allegations</u>

Each one of the five specific allegations made in Elmore's letter is discussed below.

<u>"1. Maintaining Canals in Overly Full Conditions"</u>

Canals throughout the system are generally operated with minimal freeboard, which gives the District broader capability to meet the needs of customers. At the same time, canal operations are simplified with respect to anticipated customer orders. The error associated with scheduling the delivery of water in this manner is that almost always more water than was ordered is provided.

Water deliveries are determined by a relatively simple method involving the direct measurement of water levels in front of and behind a standard-sized delivery gate (IID, 1967b, rev. 1979). The District considers this method to yield an accuracy of measurement of plus or minus 5 percent. Realizing this limitation in the accuracy of delivered water, many customers order in excess of actual crop or leaching requirements to ensure they will receive at least the amount needed to satisfy irrigation requirements.

The ability of the District to take back excess water when a farmer orders too much depends on the type of delivery operation, location of the field, and quests by other farmers who may want take the water. The system is set s unable to absorb this excess d, consequently, the water is lost to e farmers at the end of a canal or eld. Unauthorized adjustments of rm headgates, a not uncommon practice farmers and irrigators in the Imperial lley, but prohibited by District ulations (Appendix D), also adds er (reject water) to the canals.

increased incidence of canal minal spillage is one consequence operating delivery canals with imum freeboard. Department ervations and photographic ibits, such as those shown in endix F,* suggest that significant unts of unused irrigation water spilled at the terminal points delivery canals. This water is nveyed to the Salton Sea via the erconnecting system of drains.

District estimates that 1 to ercent of ordered water is rejected far- -s. This would equate to lls rom canals of 30 800 to 700 cubic dekametres (25,000 to 000 acre-feet) per year. Included Appendix F is a table showing a -year period of measured spills at end of the Rose Canal. This table compiled by the Department from ords provided by the District. The ll during calendar year 1980 was 78 cubic dekametres (3,874 acre-feet) m that canal, or 2 percent of the al water delivered to the canal ding. A rough extrapolation of that sured spill, considering the total ber of similar-sized canal spill es in the District's system, suggests t spills from such canals approximate 000 cubic dekametres (23,000 acre-t) per year. Additionally, spills m nearly 200 spill sites of lesser-ed canals may lose an estimated 000 cubic dekametres (30,000 acre-feet) annually, bringing the total magnitude of estimated canal spills to 65 000 cubic dekametres (53,000 acre-feet) per year. This quantity is approximately 2 percent of District customer-ordered water and appears to be a reasonable estimate of uncontrolled canal spills. This estimate is based upon a small amount of data.

The exhibits cited in Appendix F also give an indication of the magnitude of these spills. They show selected measurements, taken at the canal terminals, using a Clausen Weir Rule. The total quantity of canal spills at six terminals monitored by the District was 12 300 cubic dekametres (10,000 acre-feet) during 1980 (Sutherland, 1981).

Operation of the canals with reduced freeboard results in minimum flexibility to absorb and store excess irrigation water that could be returned by customers. Amendments to an original order may be requested by customers and granted by the District as provided for in its regulations (Appendix D), if the District can handle the additional water.

The District can increase its ability to control water in the system and reduce spills by any one, or all, of several means discussed in the following sections of this chapter.

"2. Absence of Reservoirs"

The absence of sufficient reservoir capacity results in the inability to store excess water as it becomes available in canals. This can result in significant spillage of water at canal terminal points, where it is lost to further agricultural use.

There are currently two regulatory reservoirs within the District. The

* It is important to note that the photographic exhibits shown in Appendix F depict conditions at a specific time and may not be representative of those over a 24-hour period.

reservoirs, the Kakoo Singh and the J. M. Sheldon, have a capacity of 395 cubic dekametres (320 acre-feet) and 740 cubic dekametres (600 acre-feet), respectively. The Singh Reservoir, which is located east of Calipatria on the East Highline Canal, began operation in February 1976. The Sheldon Reservoir is located northwest of Imperial on the Westside Main Canal; it began operation in March 1977. The District estimated that in 1978 the combined water savings from the two reservoirs approximated 41 100 cubic dekametres (33,300 acre-feet).

Land has been acquired and construction started on a third regulatory reservoir. This reservoir is designed to have a capacity of 432 cubic dekametres (350 acre-feet) and is located south of Brawley on the Central Main Canal. With completion of this reservoir, there will be one regulatory reservoir for each of the three main canals. The District estimates an additional 15 000 to 18 500 cubic dekametres (12,000 to 15,000 acre-feet) of water can be saved each year after the reservoir begins operation.

Land has also been selected for a fourth reservoir, and the District believes this land will be acquired by December 1981. In addition, 12 more sites have been identified by the District as potential reservoir sites.

The most economical and energy-efficient method of operation for regulatory reservoirs is with gravity flow, both into and out of the reservoir. The two existing reservoirs operate in this manner and it is planned that the third and fourth will operate in a similar manner.

For successful conservation of irrigation water, some of the reservoirs need to be located in a near mid-canal area so that a reasonable number of farm headgates are located both up-canal and down-canal. Thus, water becoming available from over-orders and cutbacks on the up-canal side can flow directly to the reservoir to be stored and later be served to farm headgates on the down-canal side.

According to the District, more regulating reservoirs have not been built because of their high costs and because they remove land from agricultural production. However, the District is considering land exchange as part of the negotiations for right of way for regulatory reservoirs. Under that concept, undeveloped land would be exchanged for the developed land taken out of production. Costs of land and construction for a 500-cubic-dekametre (400-acre-foot) reservoir were estimated by the District to be about $2 million. This program, in addition to other conservation work, is presently financed by a $1.62 per cubic dekametre ($2.00 per acre-foot) surcharge on water deliveries.

The cost of building the additional 13 regulatory reservoirs needed to control canal flows and minimize spills and on-farm tailwater is estimated to be $26 million. However, a system providing a high degree of control might be provided with fewer reservoirs. For one thing, it appears that, as the number of reservoirs increases, the amount of water saved by each succeeding reservoir decreases. The number of reservoirs added to the system should be determined by economic analyses, considering the operation of the reservoirs in conjunction with other alternative means of controlling the canal system. Combining additional regulatory reservoirs with more flexible scheduling and an expanded remote control system could provide an economical method of controlling water in the system.

If each of the 13 additional reservoirs could save an average of 9 900 cubic dekametres (8,000 acre-feet) annually, they would together save 128 000 cubic dekametres (104,000 acre-feet) by reducing canal spills and tailwater. The cost would be about $28 per cubic

etre ($34 per acre-foot) of water
l. cause these values are only
mpti..s, an operations study of
District's system is needed to
ide a better estimate.

Excess Water . . . Delivered
armers' Headgates"

of the issues related to the amount
ater delivered to farmers' headgates
discussed under other sections in
chapter. These factors also affect
amount of tailwater, which is the
ace water runoff from the fields
r irrigation application.

eries through farmers' headgates
the culmination of a number of
ns: the farmer's order, climate,
tional constraints of the District,
ime between District orders and
pt of water at Imperial Dam, and
s.

ordering of water by farmers is
upon their perception of field
iti . The accuracy with which
farmer is able to order the correct
nt of water may be generally
ted by incomplete knowledge of field
itions, as discussed later in
ter IV under "Alternative Irrigation
ods." The farmer also wants to be
red that a certain minimum amount
ater will be received; therefore,
rgin of safety may be added to take
of measurement error by the
ero. On the other hand, the District
rally has excess water available in
canals. The District has no precise
of ascertaining whether the farmer's
r is reasonable or unreasonable;
efore, it provides all the water
red by the farmer. The net effect
these uncertainties is the production
tailwater from the fields or rejected
ess water in the canals, as each
r tends to be on the high side.

Absence of Tailwater Recovery
ems"

wat recovery systems generally consist of three basic components: a storage sump, a pumping system, and recovery and distribution pipelines. These systems have been identified by some researchers (Merriam, 1977; University of California, 1979) as having a high potential for saving irrigation water. The University of California Cooperative Extension Service claims reclaimed tailwater seldom shows significant increase of salt content from dissolving of soil salts in a field that has been irrigated for several years (1979).

The low cost of irrigation water in the District ($6.08 per cubic dekametre, or $7.50 per acre-foot) would give farmers who do not install tailwater systems a lower operating cost than those installing such systems. Farmers who can avoid tailwater systems by conserving water in other less expensive ways, such as being more exact in determining crop/soil moisture needs or having flexibility to divert excess amounts of their ordered water to other fields, save the cost of constructing sumps, pipelines, and pumping facilities and the cost of operation, plus the loss of cultivated land needed for location and operation of the system. Estimated costs of a tailwater recovery system range from $6.50 to $20 per cubic dekametre ($8 to ($25 per acre-foot).

Tailwater recovery systems are known to be operating at only two farms within the Imperial Valley, as reported by the Soil Conservation Service, El Centro. The absence of tailwater recovery systems, together with poor irrigation practices, can contribute to excessive drain flows, causing water of moderate quality to be lost to the farmer. Also, without recovery systems, tailwater may pond on farm fields and scald crops, resulting in yield reductions. One Department observer noted that about 0.4 hectare of a 24-hectare (1 acre of a 60-acre) field suffered scalding due to ponding of tailwater, or about a 1.6 percent loss of production.

TABLE 5

TOTAL NUMBER OF FARMERS' HEADGATES RUNNING AND WASTING MORE THAN 15 PERCENT TAILWATER*

Date	Total running	Number wasting over 15% 1st check	2nd check	% assessed	Date	Total running	Number wasting over 15% 1st check	2nd check	% assessed
1980					1978				
Dec	No data				**Dec	7708	314	77	1.0
Nov	10493	534	212	2.0	**Nov	10427	441	109	1.0
Oct	15590	718	267	1.7	Oct	14145	525	115	0.8
Sep	18014	1070	417	2.3	Sep	17173	797	249	1.4
Aug	18414	936	335	1.8	Aug	17207	626	128	0.7
Jul	17093	776	254	1.5	Jul	17127	556	80	0.5
Jun	14941	759	171	1.1	Jun	14992	551	73	0.5
May	14866	741	227	1.5	May	17504	624	101	0.6
Apr	20061	1086	401	2.0	Apr	19678	638	129	0.7
Mar	14993	714	269	1.8	**Mar	13394	552	119	0.9
Feb	4933	184	84	1.7	**Feb	6069	272	50	0.8
Jan	7284	310	117	1.6	Jan	None Recorded			
	$\bar{x}$=14244	$\bar{x}$=712	$\bar{x}$=250	$\bar{x}$=1.7		$\bar{x}$=14129	$\bar{x}$=536	$\bar{x}$=112	$\bar{x}$=0.8

Date	Total running	1st check	2nd check	% assessed	Date	Total running	1st check	2nd check	% assessed
1979					1977				
Dec	9391	510	204	2.2	**Dec	6680	284	40	0.6
Nov	10750	487	179	1.7	Nov	10273	390	56	0.5
Oct	15466	650	259	1.7	**Oct	11142	561	103	0.9
Sep	17196	932	377	2.2	Sep	13721	630	137	1.0
Aug	16280	698	225	1.4	**Aug	10710	341	61	0.6
Jul	16474	516	138	0.8	Jul	20293	686	110	0.5
Jun	15601	689	155	1.0	Jun	17168	734	128	0.7
May	17408	943	289	1.7	May	17337	869	236	1.4
Apr	20495	873	153	0.7	Apr	20782	1062	228	1.1
Mar	15084	839	169	1.1	Mar	18010	1294	342	1.9
Feb	9573	559	143	1.5	Feb	12475	624	190	1.5
Jan	4895	140	44	0.9	**Jan	8438	455	189	2.2
	$\bar{x}$=14051	$\bar{x}$=653	$\bar{x}$=195	$\bar{x}$=1.4		$\bar{x}$=13919	$\bar{x}$=661	$\bar{x}$=152	$\bar{x}$=1.1

* Four-year average number of headgates running = 14,086 per month
Four-year average percent of tailwater assessments = 1.25% of total headgates running
Four-year average number of tailwater assessments = 176 per month, or 5.8 per day
Four-year average percent of headgates running checked for waste = 20.5%

** Partial data available for month

Source: Imperial Irrigation District. Water Control Section Surface Waste Report. December 1980 pring and summer, irrigation water increase in temperature by as much as ?°F) as it travels over fields. cing this water may compound problems ciated with plant scalding unless it blended with fresh irrigation water s applied through sprinklers, where has a chance to cool as it is applied.

District has, since 1964, attempted educe waste of water by discouraging discharge of excess tailwater. An rating rule in effect from 1964 to 5 set the permissible tailwater charge at 10 percent of the order. more than 10 percent tailwater was erved, then the inflow to that field reduced at the farmer's headgate by amount of the excess. This was ised in 1976 to the current rule re there no longer is a reduction inflow when excess tailwater is erved. However, when tailwater ches 15 percent of the farmer's order, District assesses a penalty of three s the rate of the total water ivery scheduled for that day pendix D). This rule was further ls as of July 1, 1981, to impose open-ended penalty assessment for onic violations of excess tailwater duction. In any calendar quarter, sons incurring a second tailwater lation will be charged a penalty of r times the rate of the total water er for the day; those incurring a rd violation will be charged a alty of five times the rate; etc.

tailwater discharging from each ld is observed by the zanjero who rates that headgate. Tailwater flows also monitored by a special unit of hydrographers (waste checkers) who assigned exclusively to that task. the tailwater flow appears excessive, is measured. If tailwater flow is nd to exceed 15 percent of the igation inflow, then the farmer is ised to reduce tailwater flow and otation made at the operating dquarters. Those fields noted to e excess flow are measured again, least 9 hours after the first measurement. If they are still flowing in excess of 15 percent of the ordered inflow, the cost penalty is assessed.

The 9-hour delay between measurements was recommended by the Water Conservation Advisory Board and established by the Board of Directors as a basis for applying the tailwater assessment. This delay period was established for two reasons: (1) to ensure that the measurements are made by two different individuals; and (2) to allow adequate time for redistribution of water on fields so as to decrease the amount of tailwater being produced. This is in recognition of the fact that changes in irrigation distribution at the head of a field frequently are not reflected in tailwater flows at the waste collection box until 3 to 4 hours after the changes have been made.

Normally, tailwater cannot be ponded on most fields without causing crop damage. The farmer can decrease tailwater flows by changing the irrigation pattern.

Table 5 is a summary of the tailwater assessments levied against District customers for the years 1977 through 1980. This table was compiled from data received from the District (December 1980). Of the total number of fields checked for excessive tailwater (approximately 20 percent of the total headgates running), about 4.5 percent on the first check and 1.25 percent on the second check had tailwater being produced at a rate in excess of 15 percent of their delivered irrigation flow rate. If an average delivery rate of about 0.2 cubic metre (8 cubic feet) per second is assumed, an estimated 30 800 cubic dekametres (25,000 acre-feet) of tailwater is produced within the District each year by those who were finally assessed a penalty for being in violation. It is obvious that tailwater is produced by the remaining 98.75 percent of irrigators who are not in violation of the rule.

Assumptions can be made that illustrate the importance of tailwater control and the magnitude of the problem. For the 5-year period 1975-79, about 3 129 000 cubic dekametres (2,537,000 acre-feet) of water was delivered annually to the farmers and about 1 077 000 cubic dekametres (873,000 acre-feet), or 34.4 percent of this amount, passed on to the Salton Sea. It was estimated that about 2 percent of that delivered went into canal spills, leaving 32.4 percent to be split between tailwater and leach water. Because there are insufficient data with which to accurately quantify leach water and tailwater, the following deductions have been made. Almost all farms produce tailwater. The quantities produced range from smaller to greater than 15 percent. Because tailwater and leach water are unknown quantities, it is believed that tailwater is at least 15 percent of the total delivery, or 469 000 cubic dekametres (380,000 acre-feet) annually, as shown graphically in Figure 5 (condition 2). Tailwater could be as much as 22 percent of the total delivery, or 688 000 cubic dekametres (558,000 acre-feet), if it is assumed that leach water is 15 percent of evapotranspiration--ET (Figure 5, condition 1). Leach water will be discussed further in Chapter IV.

"5. Water Must Be Ordered in 24 Hour Delivery Intervals"

The delivery of water to District customers is conducted in 24-hour increments. The District does provide for a reduction in an irrigation order which can apply to the last 12 hours water is run (Appendix D).

The reduction cannot exceed 50 percent or 0.14 cubic metre (5 cubic feet) per second of the original order, whichever is less, and must be requested no later than 3 p.m. of the day preceding that on which the order is to be changed.

The District does not appear to have a process to actively seek customers to take advantage of water made available by reduced orders. Such a marketing process would require additional work time to solicit customers. If this could not be handled by the existing staff, the effort would increase operating costs. Since the farmer has already paid for the water which is rejected, the District does not aggressively pursue the sale of the water a second time. However, District regulations (Appendix D) provide for customers to receive additions to their existing orders by notifying the District. If these water users are in need of additional supplies of irrigation water, they can be accommodated by notifying the District prior to 7:30 a.m. of the last day of a run and receiving up to a 50 percent increase of the confirmed order, if it is within the capability of the District to deliver the water.

Scheduling irrigation deliveries in 24-hour intervals reduces operating costs to the District. By conducting deliveries in 24-hour intervals, a normal daytime work schedule can be employed. Anticipating regular 24-hour intervals for the delivery of irrigation water permits greater accuracy in predicting customers' orders by the District. The fact that the District must place orders for water 6 to 11 days prior to its use and 3 to as much as 10 days before farmers actually order the water affects the flexibility of operations. Allowing farmers to shut off deliveries when no longer required would solve their problem of excess water but would increase the District's problem of excess water.

Some irrigation districts in the lower Colorado River Basin have adapted their delivery systems to provide irrigation water on very short notice. Among these districts are the Yuma County Water Users Association, the South Gila River and North Gila River Districts, the Colorado River Indian Reservation, and the Palo Verde Irrigation District.

These irrigation districts handle water orders in basically the same manner.

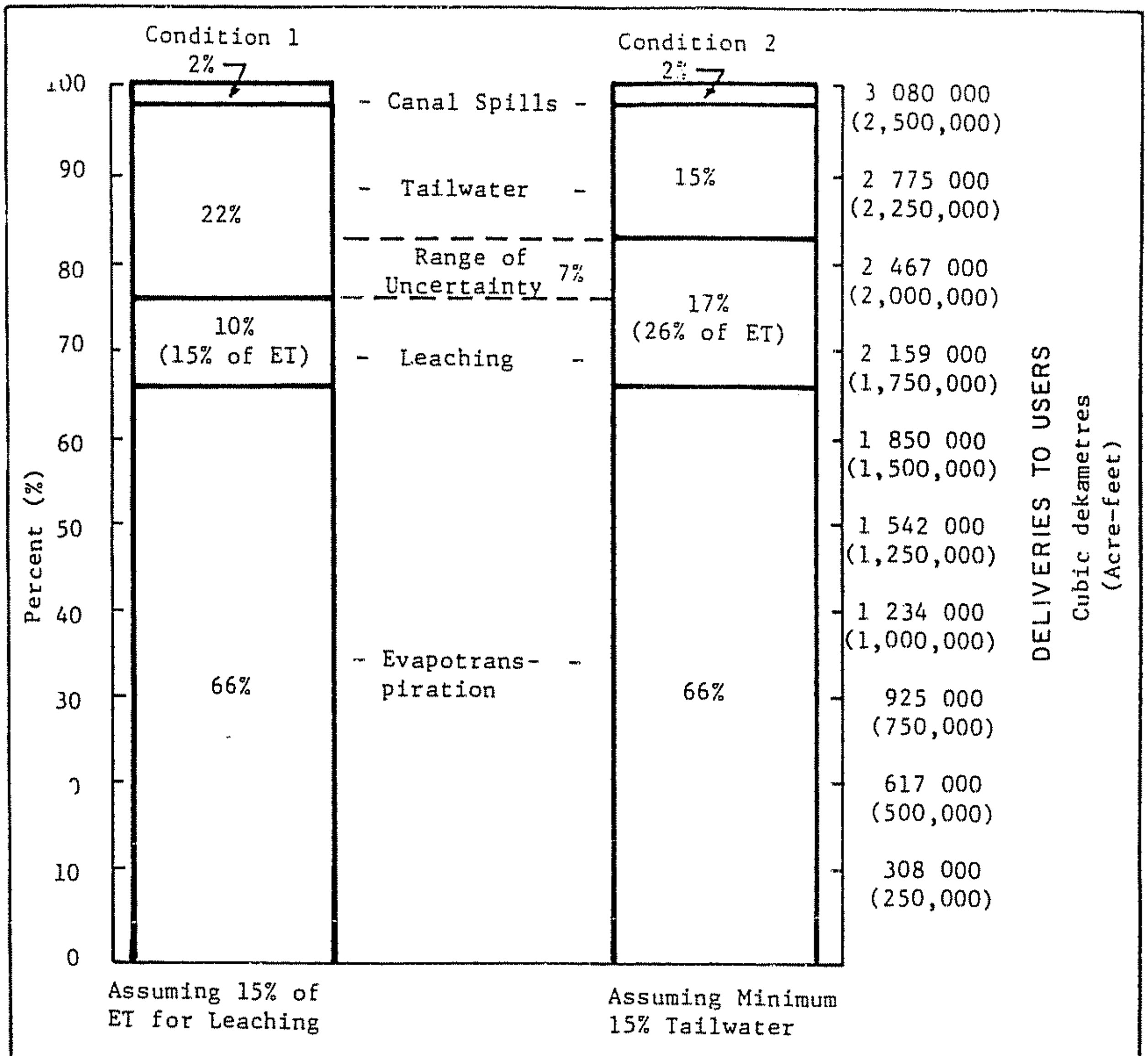


FIGURE 5 - ESTIMATED RANGE OF LEACHING AND TAILWATER PRODUCTION, IMPERIAL IRRIGATION DISTRICT

:ertain base lead time is required by : district to schedule water orders. :e an order has been scheduled, the ie for terminating the order is :ermined by the customer. Zanjeros : employed in three eight-hour shifts on the basis of a 24-hour on-call tem. In some areas within the Yuma a, stomers are allowed to ipu .te headgates to increase or decrease incoming water as required.

The continuous system of scheduling and terminating irrigation orders can reduce the incidence of tailwater production on farms, since a mandatory period during which customers must take water is eliminated. Cancellations or reductions in orders are readily accommodated by the districts in the event of on-farm irrigation equipment failure or the occurrence of rain. One physical factor that contributes to the success of these scheduling systems is that water which is not used can be returned to the Gila or Colorado Rivers. The water thus returned is deducted from the original diversion, is not charged against the user's entitlement, and is available downstream for further beneficial use.

The Imperial Valley does not have this convenient option, and its excess water is lost to the Salton Sea.

Application of a less than 24-hour time block scheduling system would require an increase in personnel and/or an expansion of personnel working period and/or an expansion of the remote-control system and regulatory reservoirs.

In the December 6, 1979, affidavit of J. Robert Wilson, Water Manager of Imperial Irrigation District, it is stated that changing the District's scheduling and water delivery methods to a more flexible operation would require doubling the zanjero staff at a cost of $2 million per year. The effect of this cost is shown on the graph in Figure 6, which gives the unit cost for a range of quantities of water saved.

Beyond the change from the existing 24-hour scheduling system, it seems probable that an increased effort to make available to customers the option to individually move deliveries of water from one headgate to another on an adjoining field on the same canal would result in better irrigation efficiencies, less tailwater runoff, and less water returned to District canals. Similarly, water savings may potentially be realized if down-canal customers had more opportunity to receive water returned to District canals. Such deliveries could be made available on short notice and delivered for variable periods, depending on water need and availability.

Further water savings could be realized if the District improved its maintenance of terminal canal gates so that leaks are reduced. Estimates of the amount of water lost to leakage through gates at terminal canal points have been made by James C. Luker, Superintendent, Irrigation Drainage, El Centro-Calexico Division, Imperial Irrigation District (U. S. District Court, 1980). In reviewing photographs of various leaks through gates, Luker has estimated the observed flows to be on the order of .014 and .021 cubic metre (0.5 and 0.75 cubic foot) per second.

Ordering irrigation water in excess of actual crop and/or leaching requirements allows farmers a working margin of water to help overcome problems associated with nonuniform application and percolation. Irrigation water ordered and/or delivered in excess of actual required amounts results in excessive tailwater and canal spills, which, in the majority of cases, is lost to the Salton Sea.

Summary of Opportunities for Saving Water, Based on the Allegations of John Elmore

The Elmore allegations concentrate specifically on the District's "wasteful and unreasonable policies and practices" and spotlight five instances, quoted at the beginning of this chapter, where he believes the District could save water. The five examples are related and tend to deal with the same quantities of water. The two separate quantities are tailwater and canal spills. With a given quantity of water in the system, decreasing tailwater can affect canal spills, if the excess water is rejected by the farmer and remains in the canal.

Canal spills are estimated to be about 65 000 cubic dekametres (53,000 acre-feet) annually, of which about 94 percent, or 62 000 cubic dekametres (50,000 acre-feet) is recoverable.

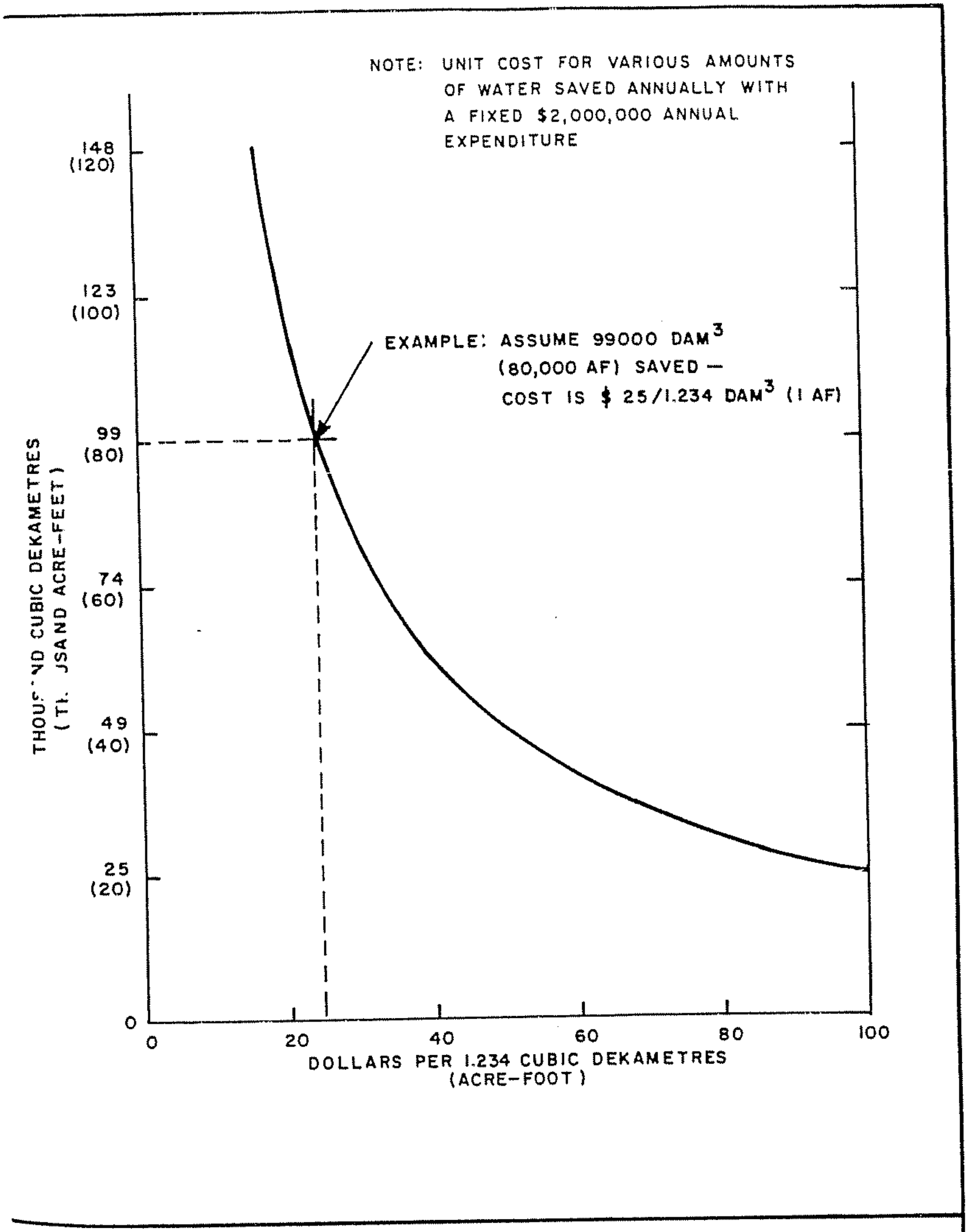


FIGURE 6 – UNIT COST OF WATER SAVED ANNUALLY BY FLEXIBLE SCHEDULING SYSTEM

...MENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1981

Assuming tailwater production for all irrigators is at least 15 percent of delivered water, it probably exceeds 469 000 cubic dekametres (380,000 acre-feet) and could be as much as 688 000 cubic dekametres (558,000 acre-feet). The combined losses for canal spills and tailwater are roughly estimated to be at least 534 000 cubic dekametres (430,000 acre-feet).

IV. OTHER OPPORTUNITIES FOR WATER SAVINGS

ddition to the opportunities for r savings discussed in Chapter III, ain other opportunities exist within District's service area. Discussion hese opportunities follows.

All-American Canal Lining

rmation derived from the USBR (USBR SIA, 1978), the United States gical Survey (1969), and the rict Annual Summaries (1955-79) ates significant loss of water s through seepage along the ned All-American Canal. The amounts eepage water lost annually from the ., as estimated by reach, are given able 6 for the 1975-79 period. The test loss is in the reach from Pilot to East Highline Canal, because of ie losses from Imperial Dam to Knob return to the Colorado River the soils from the East Highline to the Westside Main Canal have tively low percolation rates which mize losses.

1975 to 1979, the All-American l from Pilot Knob to East Highline l, 60 kilometres (37 miles) in th, was estimated to have lost 96 000 cubic dekametres 000 acre-feet) of water annually ugh seepage. It is estimated that 00 cubic dekametres (70,000 acre-) could be saved through lining reach of the Canal at a cost of million (July 1979 prices). This quivalent to $93 per cubic dekametre 5 per acre-foot) of water salvaged artment of Water Resources, st 1980).

noted that seepage water and other s water in the canal system produces rical power in hydroelectric plants ear the point of loss. Lining of the canal can result in a minor increase in flows generating hydroelectric power, if the point of delivery of the water saved is within the District, or a minor decrease, if the point of delivery is outside the District.

Main Canal and Lateral Lining

By 1979, the District had lined 1 178 kilometres (732 miles) of its main canals and laterals. The estimated amount of water saved through that lining program was 169 700 cubic dekametres (137,600 acre-feet) in 1979. The overall water conserved since the beginning of the District's canal lining program is shown in Table 7. As of June 1980, 45 percent of the District's canals and laterals had been concrete-lined.

The District plans to line an additional 834 kilometres (518 miles) of its earthen laterals and estimates an additional water saving of 123 000 cubic dekametres (100,000 acre-feet) per year.

Where District-owned canals are on land easements granted by the landowner, the District encourages landowners to participate in the canal lining program. It pays 70 percent of the cost of concrete-lining canals and all engineering and excavation costs, while the landowner covers the remaining 30 percent of the lining cost, as well as provides rights of way and any necessary dirt. An advantage to the farmer is in reduction of costs in operating and maintaining on-farm delivery facilities adjacent to the District's canal. The District's funds in this program are assigned first to lining those ditches adjacent to lands where the landowner participates. The District is currently expending about

TABLE 6

ESTIMATED SEEPAGE LOSSES IN THE ALL-AMERICAN AND COACHELLA CANALS, 1975-1979

	Length	Losses in cubic dekametres (acre-feet)				
	kilometres (miles)	1975	1976	1977	1978	1979
All-American Canal						
Imperial Dam to Pilot Knob*	32 (20)	99 600 (80,752)	116 800 (94,695)	127 300 (103,240)	92 900 (75,319)	103 300 (83,717)
Pilot Knob to Drop No. 1	26 (16)	67 200 (54,514)	71 800 (58,224)	36 000 (29,163)	64 000 (51,867)	60 000 (48,654)
Drop No. 1 to East Highline Canal	34 (21)	72 200 (58,555)	40 100 (32,543)	27 500 (22,293)	30 100 (24,407)	9 700 (7,835)
East Highline Canal to Westside Main Canal	37 (23)	10 500 (8,546)	24 100 (19,505)	22 200 (17,983)	27 800 (22,560)	15 100 (12,252)
Total	129 (80)	249 500 (202,367)	252 800 (204,967)	213 000 (172,679)	214 800 (174,153)	188 100 (152,458)
Coachella Canal						
Drop No. 1 to 6A Check**	79 (49)	158 200 (128,271)	159 900 (129,639)	139 500 (113,029)	152 800 (123,900)	165 700 (134,300)
6A Check to Milepost 90.6	67 (42)	66 300 (53,710)	41 000 (33,240)	-- --	-- --	-- --
Total	146 (91)	224 500 (181,981)	200 900 (162,879)	139 500 (113,029)	152 800 (123,900)	165 700 (134,300)

* Losses from this reach are considered Colorado River System Reservoir losses. Most of the seepage loss in this reach is assumed to reach the Colorado River through the ground water as return flow. If this reach is lined, an amount equal to salvage would have to be released to satisfy downstream obligations which would have been fulfilled by this return flow. Net diversions to Imperial Irrigation District and Coachella Valley Water District are measured at Pilot Knob, not at Imperial Dam.

** Concrete lined as of November 1980.

Source: Imperial Irrigation District, Annual Summaries, 1975-79.
U. S. Bureau of Reclamation.

TABLE 7

ESTIMATED AMOUNT OF WATER CONSERVED BY CONCRETE-LINING PROGRAM

Year	Cumulative amount of canals concrete-lined		Total estimated annual* water conserved	
	In kilometres	In miles	In cubic dekametres	In acre-feet
1954	1.29	0.80	185	150
1955	2.10	1.30	301	244
1956	4.76	2.96	686	556
1957	9.83	6.11	1 400	1,100
1958	14.84	9.22	2 100	1,700
1959	21.39	13.29	3 100	2,500
1960	27.21	16.91	3 900	3,200
1961	43.47	27.01	6 290	5,100
1962	71.90	44.68	10 400	8,400
1963	116.22	72.22	16 800	13,600
1964	197.53	122.74	28 500	23,100
1965	282.54	175.57	40 700	33,000
1966	390.75	242.81	56 200	45,600
1967	487.70	303.05	70 300	57,000
1968	563.61	350.22	81 200	65,800
1969	652.28	405.32	94 000	76,200
1970	714.63	444.06	103 100	83,500
1971	770.97	479.07	111 100	90,100
[illegible]	829.22	515.27	119 500	96,900
1973	877.41	545.21	126 400	102,500
1974	927.57	576.38	133 700	108,400
1975	989.35	614.77	142 600	115,600
1976	1 046.05	650.00	150 700	122,200
1977	--	--	--	--
1978**	--	--	--	--
1979	1 178.00	732.00	169 700	137,600

* Based on an annual average water savings of 288 cubic dekametres per kilometre (376 acre-feet per mile) and on the assumption that 50 percent of lined sections are below natural ground surface with a negligible seepage rate.

** In 1978, the District lined 30.1 kilometres (18.7 miles) of canals and farmers installed 53.8 kilometres (33.4 miles) of concrete lining. By the end of 1978, the cumulative total for all categories of canal lining, including on-farm, was 4 796.7 kilometres (2,980.6 miles).

.5 million on this program each year.

rent unit cost of lining is dependent canal size. A typical District canal ing (up to 8 metres, or 26 feet, in width) will cost about $66,000 per kilometre ($105,000 per mile). This estimate is only for lining by a private contractor, with the District performing all initial excavation at an additional cost of $2.60 to $5.25 per cubic metre ($2.00 to $4.00 per cubic yard) of material excavated. The District's lined canals have a normal useful life of 50 years before major reconstruction is expected.

The lining of the farmers' on-farm ditches (up to 1 metre, or 3.2 feet, wide and 1 metre deep), complete with field accessories (headgates, checkgates, etc.), generally costs $20,500 per kilometre ($33,000 per mile) (Merrill, 1981). The lining of farm ditches is becoming a cyclical operation in the Imperial Valley. Due to shrinking and swelling of the clay soils, salt corrosion of concrete, and damage from earthquakes, the canals and ditches suffer settling, sagging, cracking, and misalignment and must be replaced approximately every 30 years.

Scheduling of lining operations depends mainly on two parameters: (1) the District's judgment of the need for a particular section to be lined, modified by (2) the farmers' willingness to participate financially in the program at that time. The length of canal lining that can be financed each year from an essentially fixed annual capital outlay depends on the size of the canal. This has generally ranged from 32 to 56 kilometres (20 to 35 miles) per year. Based on an estimated average of 48 kilometres (30 miles) per year, the remaining 834 kilometres (518 miles) to be lined would take more than 17 years to complete. Extrapolating this further, the estimated total cost of lining the remaining 834 kilometres of canal would be 17 years at $1.5 million per year, or about $26 million, excluding inflation. Further, the capital cost (excluding interest), based on an estimated 30 years before replacement, would be about $25 per cubic dekametre ($31 per acre-foot) of water saved.

In addition to saving water, considerable saving in operation and maintenance costs is associated with the use of lined canals and laterals. Such saving includes ease of measuring water flow, rapid and accurate delivering of water from release points, rapid emptying of canals for algae control, and eliminating or getting greater control of aquatic and riparian weed growth. These savings could be increased by accelerating the lining program.

Seepage Recovery Systems

The District does not intend to concrete-line some reaches of the main canals, as the construction work would cause serious operating problems. Instead, seepage recovery pipelines have been buried parallel to the canal. The District has 10 kilometres (6 miles) of these lines that save 22 000 cubic dekametres (18,000 acre-feet) of water annually. This system should be expanded, particularly in areas where the canals traverse porous soils with high infiltration rates. Soil type would determine the location and effectiveness of the system.

The seepage recovery lines cost about $250,000 per 1.6 kilometres (1 mile) and have additional operating costs, mainly electrical energy for pumping water back into the canal. A rough estimate of the cost is about $11 per cubic dekametre ($14 per acre-foot) of saved water.

The length of unlined canals remaining after the planned lining is carried out would be about 820 kilometres (510 miles) or roughly equal to the distance planned to be lined. The District estimates that installation of seepage recovery lines would have the same potential saving as that achieved with lining, or about 123 000 cubic dekametres (100,000 acre-feet) of water. However, the seepage recovery lines are probably not as effective as lining in controlling water loss. A reasonable assumption would appear to be about 38 to 40 percent recovery, or 49 000 cubic dekametres (40,000 acre-feet).

Thus the potential saving from seepage

ery lines and lining District
ils is 173 000 cubic dekametres
),(acre-feet). This total is
it the same as the estimate made by
Department by using data of actual
er losses for the five years of
-79, as shown in Table 8. The values
en in this table for both canal lining
canal seepage recovery lines are
e used throughout the report.

e may be other conveyance losses
the drainage system that are
counted for in this calculation;
ver, there is also an offsetting
or in the evaporation from water
aces along the drainage system.
ddition, ET takes place from
atophytes along the drainage ditches.
out better data, it can only be
med that these values approximately
set each other.

her unknown factor is the effect of seepage from the Coachella Aqueduct. Before the reach through Imperial Valley was lined in 1980, it was estimated to have lost about 185 000 cubic dekametres (150,000 acre-feet) annually through seepage. This seepage (about 5.55 million cubic dekametres, or 4.5 million acre-feet) continued for 30 years and some of it percolated into the ground water. Since the aqueduct is at a higher elevation than the District drains, it is probable that some of this water enters the drains and will continue to do so for several years.

Only that portion of the Coachella Aqueduct seepage entering the Alamo River would affect the calculations in this report.

The quality of water in some District drains, such as those adjacent to unlined canals, is suitable for irrigation of crops. This water is essentially free

TABLE 8
POTENTIAL SAVING OF CANAL SEEPAGE
In cubic dekametres
(acre-feet)

Canal reach	Loss	Percent recovery	Water saving
ll American (Pilot Knob o East Highline)	96 000 (78,000)	90	86 000 (70,000)
Subtotal			86 000 (70,000)
istrict canals:			
Main canals*	96 000 (78,000)	38	37 000 (30,000)
Lateral canals**	151 000 (122,000)	90	136 000 (110,000)
Subtotal			173 000 (140,000)
Total	343 000 (278,000)		259 000 (210,000)

*M ly seepage recovery lines for controlling losses
**ly concrete-lining for controlling losses

to growers interested in pumping it from the drains and applying it on the fields. Any water used in this way would help improve the District's overall efficiency.

On-farm Land Grading Techniques

Land grading, as practiced in the Imperial Valley, is conducted so as to achieve a uniform grade of farm fields, generally between 0.1 and 0.2 percent slope, depending on soil texture. It is a necessary and continuing activity in the Imperial Valley because it contributes to maximizing crop yields, to controlling the uniformity in distribution of applied irrigation water, and to reducing surface tailwater (Gilbert, 1980; Mayberry, 1980b).

Land grading in the Valley costs $0.61 to $0.69 per cubic metre ($0.47 to $0.53 per cubic yard) of material moved. This amounts to $104 to $423 per hectare ($42 to $171 per acre). A typical farm field will not require frequent regrading; however, it will need smoothing every three or four years, depending on the uniformity of applied water desired. Estimates are that a farm which has not been regraded in 30 or 40 years could expect an increase of 10 to 15 percent in unit irrigation efficiency as a result of precision laser land grading (Hermsmeier, 1981).

In some locations in Arizona and California, farm fields are planed to a level-basin---literally no slope at all. This practice ensures maximum efficiency in the application of irrigation water and generally minimizes tailwater, and substantial improvements in irrigation efficiency have been recorded. Experiments with the level-basin technique in the Imperial Valley are currently being conducted. Limitations to expansion of its use are the farmers' inability to accurately determine the amount of irrigation water needed and the District's inability to make precise deliveries. This is because with level-basin fields, too much water can be just as damaging to crops as too little.

On-farm Maintenance of Optimum Soil Moisture

Replacing moisture in the soil profile in the proper amount and the correct time is essential for maximizing crop yields and achieving good unit irrigation efficiency. A program which accurately monitors the amount and rate of soil moisture depletion by crops can lead to more precise ordering of irrigation water actually needed, thereby reducing over-ordering and excessive tailwater and generally increasing unit irrigation efficiency, which is about 75 percent at present.

Some parts of the southwest currently have programs, called irrigation management scheduling (IMS), which have been devised to attain just these goals. IMS programs generally involve the use of a soil moisture monitoring instrument, such as a neutron probe, which can give investigators precise information of actual moisture content at various depths in the soil profile.

IMS programs are generally offered as a service by private consulting groups. They are sometimes sold as a package to growers and may include monitoring for fertilizer and pesticide requirements as well. A typical service conducted in the San Joaquin Valley of California costs growers $30 for labor and materials to sink a permanent access hole to serve as a soil moisture monitoring site. Each site can serve on the average up to 8 hectares (20 acres). The Soil Conservation Service, El Centro, reports accurate results with one access site for 32 hectares (80 acres). After the access tube is in place, moisture monitoring costs a grower $8 to $12 per 0.4 hectare (1 acre) per year (Seaton, 1981). USBR reports its IMS program in the Wellton-Mohawk Valley of Arizona

:s approximately 5. per ... ...

:use neutron probes are delicate
:truments that require careful
dl g and frequent calibrating, it is
ally advisable for farmers to subscribe
a service or organization trained in
: correct use of the probe. However,
mers can be trained to operate their
neutron probes and perform the
.itoring themselves. A neutron probe
rently costs $3,200 to $3,500. A
ining course and operating license
required before a probe can be used.
:rating costs are negligible, the time
juired to take one reading is generally
:er 10 minutes. Familiarity with the
iipment and the soil cuts monitoring
:e and number of readings.

experiments within the Imperial
.ley, the El Centro office of the Soil
iservation Service reports achieving
:t irrigation efficiencies of up to
percent by scheduling irrigation
:h the use of the neutron probe. Other
.dies utilizing the neutron probe show
ical unit irrigation efficiencies in
a Wellton-Mohawk Valley can be improved
10 to 25 percent. These studies, as
11 . others conducted in the San
aquin Valley (Fereres and Puech, 1979),
ggest a high potential for saving
rigation water at a reasonable
vestment. The Department has worked
th the Soil Conservation Service in
nducting on-farm studies of saving
rigation water by using the neutron
obe in Imperial Valley.

widespread use of the IMS approach to
:rigation scheduling could reduce the
ed for irrigation water in the
istrict. For example, an overall
erage reduction of 10 percent in
ter applied for evapotranspiration
uld save as much as 185 000 cubic
kametres (150,000 acre-feet) annually.

Alternative Irrigation Methods

he purpose of irrigation is to replace
il moisture and maintain it at a

... growth. Maintenance of soil moisture depends on several variable factors such as soil type, climatic conditions, crop water demand, and ability to measure rates of soil moisture depletion.

The predominant methods of irrigation within the Imperial Valley are border and furrow systems. Sprinkler systems have come into widespread use in the last decade for seed germination. Using sprinklers for this purpose results in water savings and uniform and dense crop stands, when compared to the once predominant method of surface irrigation for seed germination. Once a crop stand is established, the sprinkler systems are invariably removed from the field and the remaining irrigations are performed by border and furrow systems.

Water probably could not be saved through the use of sprinkler and/or drip irrigation systems as a replacement for surface systems in the Imperial Valley. Research shows that the high operating costs associated with sprinkler irrigation of alfalfa in the Imperial Valley usually make it uneconomical for applying water during an entire cropping cycle (Hagemann and Ehlig, 1980). There also exists the possibility of salt damage to certain truck crops, such as tomatoes, which can absorb salt through their foliage as it is wetted by sprinklers that apply irrigation water at a slow rate and with a dissolved salt content greater than 600 mg/L (Maas, 1980). The high rate of evaporation of water applied through sprinklers is also a critical factor in the Imperial Valley. This problem can be somewhat alleviated by irrigating at night. Such physical and economic limitations reduce the probability that sprinkler irrigation could entirely replace surface irrigation in the Valley to obtain savings in water use.

The high investment, labor, and maintenance costs of drip systems, in addition to the low capability of those

TABLE 9

AVERAGE IRRIGATED AREA, POTENTIAL EVAPOTRANSPIRATION (ET), AND EFFECTIVE PRECIPITATION FOR MAJOR IMPERIAL VALLEY CROPS

Crop	1977-79 Irrigated area*		Growing season potential ET		Estimated effective precipitation		Adjusted yearly potential ET	
	hectares	(acres)	centimetres	(inches)	millimetres	(inches)	cubic hectometres	(acre-feet)
Alfalfa	58 781	(145,250)	205	(80.6)	25.4	(1.0)	1 188.4	(963,491)
Cotton	38 125	(94,208)	104	(40.9)	20.3	(0.8)	388.3	(314,812)
Sorghum, Grain	4 144	(10,240)	74	(29.3)	12.7	(0.5)	30.2	(24,577)
Sorghum, Forage	191	(473)	81	(31.9)	13.9	(0.55)	1.4	(1,236)
Sugarbeets	19 432	(48,017)	119	(47.0)	44.4	(1.75)	223.3	(181,065)
Tomatoes	1 467	(3,625)	74	(29.0)	11.4	(0.45)	10.6	(8,625)
Barley	2 508	(6,198)	59	(23.4)	20.3	(0.8)	14.4	(11,673)
Wheat	40 864	(100,974)	64	(25.1)	20.3	(0.8)	252.2	(204,473)
Onions	3 346	(8,268)	66	(25.8)	27.9	(1.1)	21.0	(17,018)
Asparagus	1 451	(3,586)	164	(64.6)	40.6	(1.6)	23.2	(18,825)
Broccoli	957	(2,364)	31	(12.3)	27.9	(1.1)	2.7	(2,206)
Cabbage	193	(476)	44	(17.4)	30.5	(1.2)	0.8	(642)
Summer Melons	1 507	(3,724)	39	(15.3)	7.6	(0.3)	5.7	(4,655)
Spring Melons	3 079	(7,608)	54	(21.4)	10.1	(0.4)	16.4	(13,314)
Carrots	2 709	(6,694)	48	(18.8)	33.0	(1.3)	12.0	(9,762)
Lettuce	16 803	(41,521)	30	(11.9)	21.6	(0.85)	47.1	(38,206)
Squash	438	(1,082)	30	(11.8)	16.5	(0.65)	1.2	(1,005)
TOTAL	195 995	(484,308)					2 238.9	(1,815,585)

* Includes multiple-cropped areas

Source: Imperial Irrigation District, Annual Inventory of Areas Receiving Water, 1979; California Department of Water Resources, Estimated Crop Evapotranspiration in the Imperial Valley, California. Memorandum, Oct. 3, 1980; California Department of Water Resources, Coachella and Imperial Valleys Agricultural Land Use Study, 1978. District Report, July 1980.

tems to leach out soil salts, make eir use impractical for applying ti during an entire cropping cycle r the majority of Imperial Valley ops. Some experimentation with sposable "tape" drip systems does show omise for certain truck crops. Fields th such systems would have to be tated with traditional surface systems flooded between cropping seasons to successful in leaching salts.

eliminary results of such experiments e not convincing enough to foster ive promotion of the systems.

e most recent estimates of the mparative cost between the stallation and operation of various rigation systems are from Leaflet 75 of the University of California operative Extension Service (rev. 1978). is report summarizes irrigation costs the basis of total initial investment, well as continuing labor and operating sts. Variable inflation since these gures were published prevents the nt' ed use of the figures; however, e r..ative costs of the different stems may be considered to continue hold true.

sed on the report's information, the st of wheel line sprinkler systems runs percent higher than that of a furrow stem and 22 percent higher than that of rder systems on the basis of 0.4 hectare acre). Hand-moved sprinklers cost percent more than furrow and 30 percent re than border systems on the same basis. e cost of drip irrigation is 29 percent gher than furrow and 36 percent higher an border, also on the same basis.

Irrigation Efficiencies

other possible opportunity for saving er would be through improved unit igation efficiencies within the strict. To help gain perspective, a eral comparison was made with the iciencies in other irrigation tr s.

Efficiencies Within District

ET rates for major crops in the area have been estimated through the use of empirical formulas, such as the Blaney-Criddle and Penman, and measured through the use of weighing lysimeters at the U. S. Department of Agriculture, Imperial Valley Conservation Research Center in Brawley. Kaddah and Rhoades in 1976 used ET values derived from the Blaney-Criddle formula and the Imperial Valley Conservation Research Center to determine gross ET for major Imperial Valley crops for calendar year 1973. Using their ET estimates to compute the District irrigation efficiency, ET ÷ applied water x 100 percent, a result of 62.6 percent is obtained. Because soluble soil salts must be leached in Imperial Valley to retain soil fertility (Hermsmeier, 1978), a certain additional percentage of water must be applied to achieve adequate leaching.

A recent Department memorandum (1980) summarizes estimated ET for major Imperial Valley crops. These values closely agree with other available values published for the Valley. Table 9 shows average irrigated areas and potential ET for major crops in Imperial Valley for 1977-79. In this table, the ET listed represents the potential water use if all crops and all acreage used the maximum amount of water applied. The physical situations of soil variability, slow percolation, high soil temperatures, and, in the case of alfalfa, the need for frequent cuttings and mechanical harvesting result in an actual ET less than the calculated potential for Imperial Valley crops. These physical situations make conventional estimates of unit irrigation efficiency difficult. Precise estimates of unit irrigation efficiencies require accurate information on actual or empirically derived ET values, applied water, leaching fraction, variability of growing seasons, and net irrigated and multiple-cropped areas.

For this investigation, the best approach for determining total ET and District irrigation efficiency is to subtract net surface and subsurface drainage flows to the Salton Sea from the reported deliveries to users. Using average values for the 1975-79 period, the following ET value and District irrigation efficiency are derived:

Total flow to the Salton Sea less water from Mexico = 1 323 000 cubic dekametres (1,073,000 acre-feet)

Storm runoff component of Salton Sea flow
= 50.8 millimetres (2 inches) over 243 000 hectares (600,000 acres)
= 123 000 cubic dekametres (100,000 acre-feet)

Canal seepage component of Salton Sea flow
= approximately 50 percent of canal seepage from District main canals and laterals
= 247 000 cubic dekametres (200,000 acre-feet) x .50
= 123 000 cubic dekametres (100,000 acre-feet)

District deliveries to farms
= 3 129 000 cubic dekametres (2,537,000 acre-feet)

Flow to Salton Sea derived from District deliveries to farms
= total flow to Salton Sea - storm runoff component - canal seepage component
= 1 323 000 - 123 000 - 123 000
= 1 077 000 cubic dekametres (873,000 acre-feet)

ET = deliveries to farms - component of flow to Salton Sea derived from District deliveries to farms
= 3 129 000 - 1 077 000
= 2 052 000 cubic dekametres (1,664,000 acre-feet)

The District reports that the net average irrigated area for 1975-79 was 185 100 hectares (457,400 acres). On a unit basis, the net ET is then 11.09 cubic dekametres per hectare (3.64 acre-feet per acre), which is in accord with the District's reported 1967-76 average of 10.9 cubic dekametres per hectare (3.59 acre-feet per acre) (IID, 1977).

District irrigation efficiency

$$= \frac{\text{ET}}{\text{deliveries to farms}} \times 100$$

$$= \frac{2\ 052\ 000}{3\ 129\ 000} \times 100 = 65.6 \text{ percent (say 66 percent)}$$

Unit irrigation efficiency includes a 15 percent of ET leaching fraction

$$= \frac{(2\ 052\ 000) + (2\ 052\ 000 \times 0.15)}{3\ 129\ 000} \times 100$$

= 75.4 percent (say 75 percent)

The quantities of precipitation and canal seepage are the main variables involved in developing these ET and efficiency estimates. For the five years of 1975-79, the average precipitation over the Imperial Valley was 92.2 millimetres (3.63 inches). Generally 35 percent of the annual precipitation is consumptively used by crops and other plants in the Valley; when applied to 1975-79, this would equate to 33 millimetres (1.3 inches). Of the remaining 59.2 millimetres (2.33 inches), 50.8 millimetres (2 inches) is estimated to have entered the New and Alamo Rivers as storm runoff over 243 000 hectares (600,000 acres) of the rivers' drainage area within the Valley. The remaining 8.4 millimetres (0.33 inch) was either directly evaporated, deep percolated, or ran off to the Salton Sea directly or via subordinate stream channels.

Annual canal seepage losses within the service area of the District have been estimated to be 247 000 cubic dekametres (200,000 acre-feet), as shown in Table 8. Of this amount, half is estimated to be intercepted by tiled and open drains, which convey the water into the New and Alamo River channels. The remaining seepage losses enter the Salton Sea via subsurface

: and subordinate stream channels; p percolate; evaporate from soil, er, nd stream surfaces; or are sumptively used by crops or eatophytes along river, stream, drainage channels.

ure 7 illustrates the relationship ng water deliveries to farms, veyance losses, precipitation, and vs to the Salton Sea. As shown in s figure, flows to the Salton Sea more closely influenced by iveries to farms than by either veyance losses or precipitation.

Report for General Soil Map, prepared the Imperial Irrigation District and Soil Conservation Service and ished in 1967, states there are oil associations (a combination of types) within the Imperial Valley. teen support irrigated agriculture. s characterized as having slow eability underlay 85.5 percent of irrigated acreage in 1967. The ability of these soils, especially r ect to permeability, must be ide..ed by farmers when determining rrigation order.

erd, et al., (1979) determined that our representative Imperial Valley s, two were insufficiently leached r normal irrigation practices and were excessively leached. Those fficiently leached, the Imperial Meloland, represent 40.5 percent ll soils in the Valley, or 66 percent he irrigated agricultural soils. The ssively leached soils, the Holtville Indio, represent 13.5 percent of ey soils, or 24 percent of the gated agricultural soils.

arch in the Imperial Valley suggests because of the variability of soil s, slow percolation of water through Valley soils, and excessive soil eratures, leaching is not always ate (Lonkerd, et al., 1979; Gilbert, . A leaching requirement of 5 to rcent of estimated ET is considered pr e by some Imperial Valley farmers; however, due to the physical conditions mentioned above, part of the water applied for leaching does not percolate and generally results in surface tailwater (Welch, 1980; Gilbert, 1980). Reports published in 1962 and 1964 by the U. S. Department of Agriculture suggest leaching fractions ranging from 12 to 33 percent of ET should be applied to major Imperial Valley crops to maintain a favorable salt balance in the Valley and to optimize crop yields. Based on these reports, the average recommended leaching fraction for the Valley is 15 percent of ET. This leaching fraction was confirmed by Hermsmeier in 1981, who indicates that, although it varies greatly, the average in the Valley is between 10 and 15 percent of ET.

Calculations made for this report indicate that the average leach water application in the Valley may be considerably higher than is generally thought. Unfortunately, leach water and tailwater cannot be separated because no reliable data are available. Approximately 688 000 cubic dekametres (558,000 acre-feet) of tailwater and excess leach water is in the drain water entering Salton Sea. Tailwater was estimated to be at least 469 000 cubic dekametres (380,000 acre-feet) in Chapter III, leaving at least 220 000 cubic dekametres (178,000 acre-feet) of excess leach water.

By adding 15 percent for leaching, a unit irrigation efficiency of 72 percent can be calculated using data from the Kaddah and Rhoades study. This percentage closely approaches the 70 percent irrigation "district efficiency" in 1978 reported by the USBR and shown in Table 10. This table shows that the District's "district efficiency" is higher than that of 10 other Colorado River area irrigation districts and Indian tribe projects.

Comparison with Other Districts

To make a general comparison among

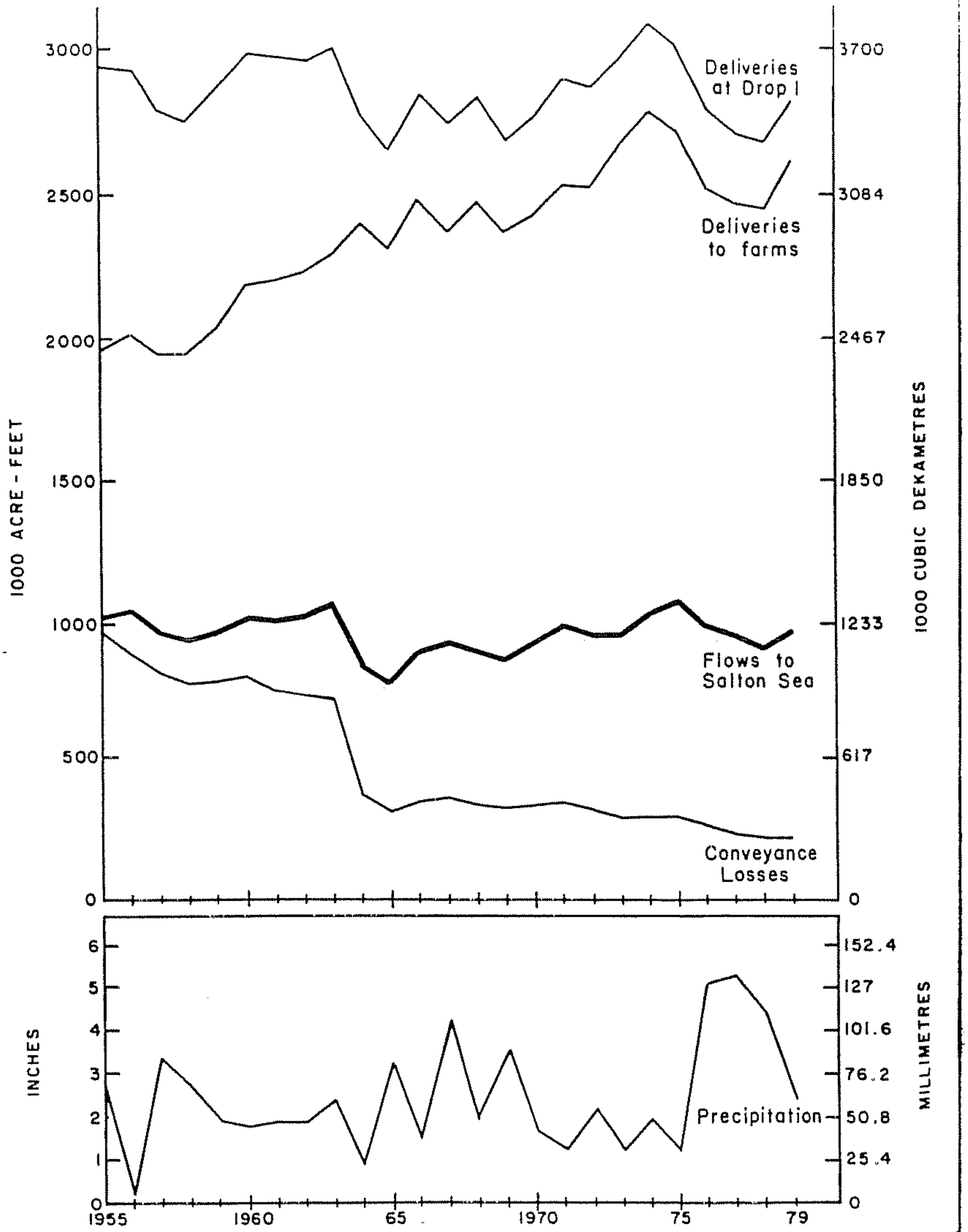


FIGURE 7 - WATER DELIVERIES, CONVEYANCE LOSSES, PRECIPITATION, AND FLOWS TO SALTON SEA, IMPERIAL IRRIGATION DISTRICT, 1955-79

DEPARTMENT OF WATER RESOURCES SOUTHERN DISTRICT, 1981

TABLE 10*

DELIVERY EFFICIENCIES OF IRRIGATION DISTRICTS

In percent

	1975	1976	1977	1978
Imperial Irrigation District				
unit efficiency	73	80	81	77
district efficiency	65	71	73	70
Coachella Valley W.D.				
unit efficiency	51	50	55	53
district efficiency	43	44	46	46
Reservation Div. I.D.				
unit efficiency	45	47	58	60
district efficiency	36	38	47	50
Y.C.W.U.A. (Valley Div.) I.D.				
unit efficiency	64	80	71	72
district efficiency	49	60	54	52
Yuma Mesa Irrig. & D.D.				
unit efficiency	33	33	29	32
district efficiency	30	30	27	30
Unit "B" Irrig. Dist.				
unit efficiency	33	32	35	38
district efficiency	32	31	33	36
Yuma Irrigation Dist.				
unit efficiency	62	63	61	61
district efficiency	59	61	59	53
North Gila Irrig. Dist.				
unit efficiency	29	40	46	42
district efficiency	28	30	43	40
Wellton-Mohawk Irrig. Dist.				
unit efficiency	55	52	63	64
district efficiency	50	47	57	57
Colorado River Indian Tribes				
unit efficiency	57	65	76	64
district efficiency	44	50	58	48
Palo Verde Irrig. Dist.				
unit efficiency	46	33	45	42
district efficiency	36	26	35	33

* This table is based on Exhibit C from an "Affidavit of Maurice N. Langley..." in Civil Action No. 76-10957 in United States District Court, (no date).

Source: U. S. Bureau of Reclamation, unpublished, 1979.

TABLE 11
DISTRICT AND CONVEYANCE SYSTEM EFFICIENCIES
CENTRAL VALLEY AND IMPERIAL IRRIGATION DISTRICTS, 1979

District name	Irrigated area hectares (acres)	Water source*	Delivery system	Irrigation type	District efficiency	Conveyance system efficiency
Westlands W.D.	221 400 (547,000)	San Luis Reservoir	Closed conduit	70% surface border and furrow 30% sprinkler	70%	98%
Fresno I.D.	82 200 (203,000)	Pine Flat Dam, Kings River	Open, unlined canals	80% surface border and furrow 10% sprinklers 10% drip	58%	75%
Corcoran I.D.	20 100 (49,700)	Kings, Kaweah, and Tule Rivers	Open, unlined canals	100% surface border and furrow	65%	75%
Tulare Lake Basin W.S.D.	69 200 (171,000)	Pine Flat Dam, Kings River, SWP	Open, lined and unlined canals	100% surface mainly border	70%	90%
Buena Vista W.S.D.	25 100 (62,000)	Lake Isabella, Kern River, SWP	Open, lined and unlined canals	100% surface mainly border	77%	65%
Imperial I.D.	186 000 (460,000)	Colorado River, All-American Canal	Open, unlined canals	100% surface border and furrow	66%	90%**

Source: San Joaquin District of Department of Water Resources
Fresno County Farm Advisor
Imperial Irrigation District

*Ground water blended with surface water in all Central Valley irrigation districts.
**Average of 1975-79 data.

Note: Excessive water applied to crops in the San Joaquin Valley generally percolates to ground water and can be retrieved for further beneficial uses.

erial Irrigation District operations
i those of Central Valley irrigation
sti ts, the following information was
npiled from discussions with various
nbers of the Department staff who are
miliar with California irrigation
actices. A total of five Central
lley irrigation districts were compared:
stlands Water District, Fresno; Fresno
rigation District, Fresno; Corcoran
rigation District, Corcoran; Tulare
ke Basin Water Storage District,
rcoran, and Buena Vista Water Storage
strict, Buttonwillow. Information on
ese is given in Table 11.

e crops grown within these districts
e similar to those in the Imperial
lley, namely, small grains, cotton,
gar beets, alfalfa, and truck crops.
ne of the districts have additional
eas of extensive orchards and
neyards, e.g., Fresno Irrigation
strict. Irrigated area ranges from
proximately 20 100 hectares (49,700
es) in the Corcoran Irrigation District
221 400 hectares (547,000 acres) in
e W tlands Water District. Irrigated
reage in the Imperial Valley was
5 200 hectares (460,000 acres) in 1979.

ils within these districts are somewhat
mparable to those in the Imperial
lley, being of fluvial origin: clay,
ay loams, and sandy loams.

st Central Valley water districts
ntioned receive irrigation water via
en, unlined canals. Westlands, Tulare,
d Buena Vista districts additionally
ceive water from the concrete-lined
lifornia Aqueduct. Westlands, which
served by the California Aqueduct
ter releases into the Delta-Mendota
nal, delivers irrigation water to
rms by buried pipeline. Water for
rigation is derived from several
rface sources, which include the
ngs, Kaweah, Tule, and Kern Rivers,
ke Shasta, USBR (via Delta-Mendota
nal), and State Water Project via
California Aqueduct.

in ater is pumped and used for irrigation in all the districts.

Major water storage features exist within 160 kilometres (100 miles) of each district. Major reservoirs serving the districts in the San Joaquin Valley are Pine Flat Lake, Lake Kaweah, Lake Success, Lake Isabella, and San Luis Reservoir.

Water quality is generally very good in comparison with that of Colorado River water: Kaweah River at Terminus Dam = 65 mg/L TDS content; Kings River near Trimmer = 30 mg/L TDS; Tule River below Lake Success = 162 mg/L TDS; Kern River at Isabella Dam = 69 mg/L TDS; and State Water Project at O'Neill Forebay = 160 mg/L TDS, at Kettleman City = 203 mg/L TDS, and at Buena Vista Pumping Plant = 193 mg/L TDS. (The State Water Project values are averages for 1980.) TDS content of Colorado River water delivered through the All-American Canal averages 890 mg/L.

Furrow and border surface irrigation techniques predominate in the Central Valley districts. Westlands Water District is an exception; sprinkler systems are common there because the district is young and was originally developed on deep well water. The price of obtaining water was initially high, which offered an incentive to apply water with maximum uniformity and efficiency.

Central Valley and Imperial Valley district irrigation efficiencies are above average for the State: between 60 and 70 percent. Westlands Water District has achieved an even higher efficiency, estimated to be between 70 and 80 percent (Morris, 1981; Stromberg, 1981). The common use of sprinkler irrigation systems, the practice of IMS, and the accurate measurement of irrigation water delivered through meters has contributed to its irrigation efficiency. Tailwater recovery systems are popular throughout most of the Central Valley, partly because there are no drains into which tailwater can be directed.

The very fine-textured soils in some of the districts and the very low natural topographic gradient combine to produce drainage difficulties on many farms. Much tile drainage has been installed in an effort to counteract drainage problems, effluent from these drains being either spread at evaporation ponds or discharged into the San Joaquin River or, in the case of Westlands Water District, into the San Luis Drain. Irrigating with the high quality water causes problems of sealing in some soils and the practice of blending lower quality ground water with incoming surface water is common.

The fact that excess applied water can be used beneficially by others adds to the overall Central Valley district irrigation efficiencies. In the Buena Vista Water Storage District, surface runoff generally flows into drains where farmers downstream pick it up for irrigation of their fields. Other excess surface water contributes to ground water replenishment.

The price of irrigation water in these districts is reported to be between \$9.70 and \$29 per cubic dekametre (\$12 to \$36 per acre-foot). The higher price for water results from the common practice of blending one part ground water (cost of \$56 per cubic dekametre, or \$69 per acre-foot) with three parts surface water priced at \$6.50 per cubic dekametre (\$8.10 per acre-foot). Irrigation water within Imperial Irrigation District is priced at \$6.08 per cubic dekametre (\$7.50 per acre-foot).

Water conservation management practices are used most intensively in the Westlands Water District. In addition to the common use of tailwater recovery systems, IMS is practiced by many growers. This service is provided at a cost of \$8 - \$10 per 0.4 hectare (1 acre) per year. The service is mainly privately provided; however, the Westlands Water District does have some technicians who assist in the program. Estimated ET rates for major crops are reported weekly in the local newspapers.

When Imperial Irrigation District is compared with districts in the Central Valley, overall district irrigation efficiency in Imperial Valley is only about 2 percent below the average Central Valley district efficiency, while average conveyance efficiency is 10 percent higher than that in the Central Valley districts. Water conservation activities in the District have significantly improved irrigation and conveyance efficiencies in the Imperial Valley over the last two decades.

Summary of Opportunities to Save Water

There are opportunities for saving water in the District system in addition to those involved in the practices noted in the Elmore allegations. Department calculations indicate lining a portion of the All-American Canal from Pilot Knob to the East Highline Canal can produce an estimated savings of 86 000 cubic dekametres (70,000 acre-feet) per year. Lining an additional 834 kilometres (518 miles) of distribution canals would save an estimated 136 000 cubic dekametres (110,000 acre-feet) per year. Expansion of the seepage recovery system along unlined canals could save up to 37 000 cubic dekametres (30,000 acre-feet) per year.

The proportion of water contributed as tailwater or leach water within the District is unknown. From measured drain flows, it is known that 34 percent of delivered irrigation water is not consumptively used on farms. It is believed that approximately 2 percent of overall deliveries are spilled at the ends of canals. Therefore, the remaining 32 percent must come from tailwater and leach water. The range in water which ach component may be contributing is illustrated in Figure 5.

xpert opinion indicates the average eaching fraction to be approximately 5 percent of ET (or 10 percent of verall deliveries). If this is the ase, tailwater flows could be as high s 22 percent of District deliveries. onversely, the leaching fraction may e much higher, ranging to 26 percent T (17 percent of overall deliveries), nd tailwater would then be about 5 percent of the overall deliveries.

f the average leaching fraction is ubstantially over 15 percent of ET, there would be an opportunity to save water by reducing it through more accurate methods of determining and accomplishing leaching in Valley soils. Leach water excess to that which expert opinion says is adequate for leaching in the Imperial Valley could be as much as 220 000 cubic dekametres (178,000 acre-feet).

Thus, there is an overall opportunity for saving, beyond that identified in Elmore's allegations, of about 479 000 cubic dekametres, or 388,000 acre-feet (leach water of 220 000 cubic dekametres + canal seepage of 259 000 cubic dekametres).

Other rights?

V. POTENTIAL USES FOR SAVED WATER

There are numerous potential uses for water that might be made available as a result of improving conservation practices in the District and lining the All-American Canal. Some of the uses would be within the District and others would be outside. Some potential uses could require new agreements or changes in existing institutional arrangements for implementation.

The discussion deals, with (1) possible uses of Colorado River water that might not be needed to maintain present production in the Imperial Valley if improved conservation practices were followed, (2) possible uses for this water outside the District, and (3) potential uses of the present drain water.

Possible Uses of Colorado River Water by the District

It is emphasized that the water which might be saved is, in fact, water that is now diverted from the Colorado River under the apportionment to the Imperial Irrigation District. To the extent that the District can make beneficial use of that water, it has the option to do so. The alternative potential uses described in this chapter illustrate the range of values to be considered in justifying the expenditures necessary to save portions of the water now lost.

Existing District Lands

The District now diverts at Imperial Dam and receives at Drop 1 water in excess of its present perfected right. This excess amounts to 370 000 cubic dekametres (300,000 acre-feet) at Imperial Dam and 247 000 cubic dekamatres (200,000 acre-feet) at Drop 1. After the Central Arizona Project comes on line, the District will have to save this amount of excess water to maintain its present irrigated area.

West Mesa Lands

The District has stated that irrigating lands in the West Mesa area will have high priority for any conserved water. The West Mesa contains 8 000 to 40 000 hectares (20,000 to 100,000 acres) of gently sloping loamy sands, which have a potential for being developed for agriculture.

Most of the soils in the area have a low inherent fertility and low water-holding capacity (IID, 1967a); therefore, substantial soil amending would be needed to improve soil conditions for production. Also, the West Mesa lands are 8 to 30 metres (25 to 100 feet) higher in elevation than the closest District canal, and water for irrigation would have to be pumped from the canal to the fields. An extension of the Westside Main Canal would be the likely source for delivery of this water.

The use of Federal lands for right of way would need approval of the Secretary of the Interior before much of the West Mesa lands could be irrigated. Also, the District should investigate the legal and institutional considerations regarding the use of conserved water on new land within the District.

Other Possible Uses of Colorado River Water

Mexican Treaty Water

International agreements guarantee quality and quantity of Colorado r water delivered to Mexico. ever, Mexico has had problems with qu ity of the water delivered ıss the border, and the United tes has found that permanent utions, such as desalting, are ensive.

the District reduces its water is by conservation programs, it ld reduce its diversions from the orado River. The increased River ws would assist the United States meet its commitments to Mexico, n the possibility of temporarily ucing the demand on the planned eral desalting facility in Yuma, zona. This could result in an rgy savings to the United States.

hella Valley Water District

hella Valley, through the Coachella ley Water District, uses Colorado er water for irrigation. Its water its are in the same block as are se of Imperial Irrigation District ar higher in priority than those gned to coastal Southern California ole 3). Further, a spokesperson for hella Valley Water District* has ted that it can beneficially use salvaged water not used by the erial Irrigation District.

Coachella Valley has about 000 hectares (96,000 acres) of igable land, of which about 24 000 tares (60,000 acres) is now under igation. The remaining land could cultivated if water were available.

ng the Colorado River

October 1980, Public Law 96-375 was sed by the U. S. Congress authorizing Secretary of the Interior to engage feasibility investigations of certain water resource developments. Item 13 of this act deals with the feasibility of obtaining a water supply of up to 12 300 cubic dekametres (10,000 acre-feet) per year "for existing and potential domestic, recreational, and municipal water users along the Colorado River in California [such as the City of Needles] who do not hold water rights or whose rights are insufficient to meet their requirements." Reduced diversions from the River to the District may provide the supplies needed to assist these water users.

Coastal Southern California

Diversions to coastal Southern California will be decreased when the Central Arizona Project begins operation after 1985, forcing Southern California to import more water through the State Water Project (SWP). If the Imperial Irrigation District reduced its water needs and diversions from the Colorado River through conservation programs, the water left in the river (savings) could be made available to other Colorado River water users. If the water could be made available to coastal Southern California, that area could reduce its purchase of SWP water by the same amount, temporarily reducing demands on the SWP system.

Water delivered to coastal Southern California from either the Colorado River or the Sacramento-San Joaquin Delta (i.e., SWP) must be pumped. The costs of electrical capacity and energy represent the major portion of water delivery costs. The energy required to deliver 1.23 cubic dekametres (1 acre-foot) of Colorado River water is about 2000 kilowatthours, while the energy required to deliver the same amount of SWP water is 3200 to 3300 kilowatthours, depending on the point of delivery.**

Lowell O. Weeks, General Manager-Chief Engineer, at Southern California Water Conference meeting, May 18, 1981.

Beginning in 1984 with the completion of the William E. Warne and Alamo (formerly Cottonwood) Powerplants, 2622 to 3216 kilowatthours will be required to deliver SWP ater.

Another factor to be considered when contemplating the reduction of SWP imports to Southern California through the increase of Colorado River imports is the difference in water quality. SWP water delivered to Southern California has a TDS content of about 250 mg/L, while that of Colorado River water (on the Colorado River Aqueduct near San Jacinto) is about 700 mg/L. The higher salt content of the Colorado River water results in an estimated average increase in water use penalty costs of $44 to $56 per 1.23 cubic dekametres (1 acre-foot) for municipal water users when compared with the 500 mg/L blended water now served by The Metropolitan Water District of Southern California (MWD), which is about 50 percent SWP water and 50 percent Colorado River water.

The approximate cost of reducing the salinity by 200 mg/L (i.e., 700 mg/L to 500 mg/L) using the reverse osmosis desalting process and blending is about $89 per 1.23 cubic dekametres (1 acre-foot) (1979 costs), using about 760 kilowatthours of energy per 1.23 cubic dekametres. These estimates are based on Orange County Water District's operational costs of its 19 megalitres (5 million gallons) per day reverse osmosis system (Cline, 1979).

Facilities for transporting water to coastal Southern California exist and excess capacity will be available after 1985; however, a spokesperson for MWD* has stated that, because of the higher priority of Colorado River agricultural contractors within California and other factors cited in this report and in correspondence presented in Appendix G, "MWD does not believe it would be practical to plan on the use of salvaged IID water within its area... We see no practical way in which Metropolitan can acquire any permanent rights to water salvaged within IID, and it would be misleading for the Department to put out a report which raises this possibility as though it had real credibility".

Any salvaged water made available would have no effect on the Peripheral Canal, which is a multipurpose project vitally needed to correct existing water quality and fishery problems in the Sacramento-San Joaquin River Delta. On April 16, 1981, the Department issued a statement explaining the need for the Peripheral Canal and other future elements of the SWP. This statement is given in Appendix H.

Potential Uses for Drain Water

Drain water now entering the Salton Sea from the Imperial Valley has potential uses. Diverting this water would reduce the rate of rise of the Sea level; it would even lower and provide an opportunity to stabilize the Sea level.

Expansion of Wildlife Preserves

It has been proposed that the wildlife preserves along the southeastern shore of Salton Sea be expanded. Drain water from New and Alamo Rivers would be used for growing food for waterfowl. A proposal by the California Waterfowl Association would use up to 247 000 cubic dekametres (200,000 acre-feet) annually.

Development of Geothermal Power

Four major known geothermal resource areas are in Imperial Valley. Water from irrigation drains could be used for geothermal power plant cooling water and for injection to replace hot brines extracted to develop power. Filings for water rights to divert flows from the New River for these uses have been made by Chevron USA, San Diego Gas and Electric Co., and City of Los Angeles, Department of Water and Power.

* David N. Kennedy, Assistant General Manager, at Southern California Water Conference meeting, May 18, 1981.

ction of Salton Sea ...

rimental work with salt-tolerant
s licates that drain water could
sed for irrigation. Some of the
tolerant crops are barley, sugar-
s, and cotton. Other slightly
tolerant crops are tomatoes,
coli, spinach, alfalfa, and rice.

rse Impacts on Fisheries, Recreation

ction in the inflow to the Salton would alleviate the threat of ating developments rimming the However, significantly reducing inflow would also: (1) lower the l of the Sea; (2) increase the ntration of salt dissolved in water; and (3) isolate shore lopments from the water's edge.

taining water quality in the Sea ritical to the continuation of a thy fishery. In the past several rs, the quality has been reasonably le. However, as the Sea recedes, quality will deteriorate, ang ing the fishery. Research by Ca fornia Department of Fish and e and others suggests that the ee species of sportfish within the , bairdiella (Bairdiella icistia), go (Anisotremus davidsoni), and ngemouth corvina (Cynoscion thulus), will experience adverse siological impacts if salinity of water rises above 40 000 mg/L sker, et al., 1972; Brocksen and e, 1972). Current (September 1981) inity in the Sea is 38 800 mg/L, and USBR has projected it to surpass 000 mg/L by as early as 1990, with or thout reduction in agricultural runoff m the Imperial Valley (USBR, 1981). ere is some evidence to suggest that bairdiella and orangemouth corvina tolerate a gradual increase in linity to concentrations as high as 000 mg/L (Hanson, 1970).

rge flocks of ducks, geese, and shore rds are attracted to the several dlife management areas on the shore of the Salton Sea and along the northern course of the Alamo River. These facilities rely on agricultural drainage water to provide a suitable aquatic habitat for bird sanctuaries and the production of forage vegetation. The rise in the Sea level has inundated a portion of the shoreline area of the Salton Sea National Wildlife Refuge, reducing its size.

Although drainage water generated in the Imperial Valley is the primary source for maintenance of the surface level of the Sea, no means exist for regulation of these flows. The Sea serves as a repository for drainage water, and its water surface elevation has fluctuated toward higher levels with agricultural expansion. These higher levels have resulted in nearly $22 million in damages to Federal, State, and private shoreline properties. No future water surface elevation can be guaranteed because of the variability in precipitation and evaporation over the Salton Sea's 21 650-square-kilometre (8,360-square-mile) natural drainage area and the variability of irrigation practices in the Imperial and Coachella Valleys. The reduction of inflow rate might provide conditions which would stabilize or minimize the fluctuation of the Sea level. However, it could also cause a significant drop in the water surface. Table 12 was developed to provide an approximation of the magnitude of the possible decline in the elevation of the Sea. The Sea elevation calculations for the table assume that the water identified as the amount that could be saved in the District (454 000 cubic dekametres, or 368,000 acre-feet) would be used in the District at an efficiency of approximately 75 percent, with 25 percent flowing to the Sea. Calculations in the table were not carried to the stabilization point.

Legal and institutional concerns in development of the Sea can be found in a Federal-State feasibility report, "Salton Sea Project, California", April 1974, prepared by the U. S. Department

TABLE 12

ESTIMATED LOWERING OF SALTON SEA FROM REDUCING AGRICULTURAL DRAIN WATER

Year	In 1,000 acre-feet[a]						
	Volume[b] of Salton Sea	Total inflow to Sea	Inflow reduction below 1981	Outflow from Sea (evaporation)[c]	Change in storage	Surface area[b] of Sea, in acres[a]	Surface elevation of Sea, in feet[a]
1981	7,220	1,541[d]	0	1,445	0	244,000	-227.0[e]
1982	7,316	1,471	70	1,452	96	245,200	-226.5
1983	7,335	1,401	140	1,452	19	245,200	-226.5
1984	7,284	1,331	210	1,448	-51	244,500	-226.8
1985	7,167	1,265	276[f]	1,442	-117	243,400	-227.4
1986	6,990	1,265	276[f]	1,427	-177	241,000	-228.0
1987	6,828	1,265	276[f]	1,420	-162	239,750	-228.5
1988	6,673	1,265	276[f]	1,409	-155	237,920	-229.2
1989	6,529	1,265	276[f]	1,397	-144	235,890	-229.9
1990	6,397	1,265	276[f]	1,389	-132	234,640	-230.4

a/ Acre-feet x 1.2335 = cubic dekametres; acres x 0.40469 = hectares; feet x 0.3048 = metres.

b/ Volume and surface area derived from area capacity curve in U. S. Department of Interior - The Resources Agency "Salton Sea Project, California", April 1974.

c/ Evaporation assumed to be 1800 millimetres (71 inches) per year over the surface area of the Sea.

d/ Initial inflow assumed to be equal to the total for 1980 (Table 1).

e/ Initial surface elevation is the average for January through September 1981.

f/ Assume 75 percent of saved water used on expanded District crops becomes ET (368,000 af x 0.75 = 276,000 af) and 25 percent flows to Salton Sea.

of the Interior and The Resources Agency of California. The report was submitted by the secretaries of the two agencies, but no funds have been allocated for implementation.

Major issues discussed in the report are: (a) continuation of the present sources (and amounts) of drain water to the Sea; (b) flooding rights up to the anticipated maximum water levels; (c) extractions of ground water in the East Mesa that wou affect subsurface flows into the Sea; (d) effect of possible outstanding wat right claims; and (e) benefits from th project to riparian owners offsetting detriments that might be claimed by re of lowering (or increasing) Sea levels

Several Federal, State, and local age would be involved in solving the lega and institutional problems of the Sea.

VI. SIGNIFICANT FINDINGS

On the basis of this investigation, the Department of Water Resources has determined that water losses are occurring within the Imperial Irrigation District's water supply and distribution facilities and elsewhere in its service area. It is the Department's opinion that certain of these losses can be reduced or prevented. This chapter highlights the more significant findings.

The water losses can be classified into three general categories: (a) seepage from unlined canals in semipervious to pervious soils; (b) losses due to spillage because the existing facilities cannot store much of the water which, once ordered, is rejected by the farmers; and (c) on-farm losses associated with the farmers' failure to accurately predict irrigation needs and to adhere to good irrigation practices.

Significant Losses

The most significant losses in these categories are:

Seepage from Canals

1. Seepage losses from the unlined All-American Canal are substantial. Lining portions of the canal traversing pervious soils could realize significant savings of water.

2. Seepage losses from the unlined portions of the District's main and lateral canals are also significant. The District's program for lining canals and installing seepage recovery systems will reduce these losses. The current rate of progress of the program, however, is such that it will take 15 to 20 years to complete the lining. Acceleration of the program would realize earlier large water savings.

Losses from Spillage

1. Fresh water, at times, is spilled from the terminal points of several of the canals directly into drains and thence to the Salton Sea. This loss of water could be reduced if additional reservoirs, similar to the two existing regulatory reservoirs, were constructed at strategic locations. The District has a third reservoir under construction, pointing to the fact that early construction of additional reservoirs would realize greater savings.

2. Excess deliveries are sometimes made at farmers' headgates because of imprecision in estimating needs. These excess deliveries, plus spills at canal terminals, can be reduced by expansion of the remote control monitoring and operation system to additional canal structures and checks. Again, early installation of additional equipment would provide greater savings.

3. Excess tailwater that spills into the drains results from the delivery of excessive amounts of irrigation water. This loss can be reduced by providing more flexibility of scheduling of farm deliveries. Additional water control features would make flexible scheduling more practicable.

On-farm Losses

1. Unit irrigation efficiency in the District is estimated to be about 75 percent. This can be improved and losses from runoff of excess

tailwater reduced by use of precision grading methods and better irrigation practices.

2. Runoff of excess tailwater to drains can also be reduced in some instances, by installation of tailwater recovery systems, which would conserve water through reuse of the tailwater.

3. Further improvement in unit irrigation efficiency can be achieved through programs providing advice on irrigation management scheduling. Such programs are now being sponsore by the District.

Table 13 gives an idea of the quantities of water now being lost and the amounts that could be saved through implementati of the measures outlined above. Figure shows graphically the relative magnitude

TABLE 13
ESTIMATED QUANTITIES OF WATER BEING LOST AND THAT COULD BE SAVED
In cubic dekametres
(acre-feet)

Source of saved water	Estimated loss	Estimated amount to be saved
District Controlled		
Lining All-American Canal	96 000 (78,000)	86 000 (70,000)
Lining main canals and laterals	151 000 (122,000)	136 000 (110,000)
Seepage recovery lines	96 000 (78,000)	37 000 (30,000)
Canal spills (regulatory reservoirs, automated control system, and flexible scheduling)	65 000 (53,000)	62 000 (50,000)
Subtotal	408 000 (331,000)	321 000 (260,000)
Farmer Controlled		
Leach water (IMS, improved irrigation practices, and land leveling); Tailwater (improved irrigation practices, flexible scheduling	703 000 (570,000)	220 000 (178,000)
Subtotal	703 000 (570,000)	220 000 (178,000)
Total	1 111 000 (901,000)	541 000 (438,000)

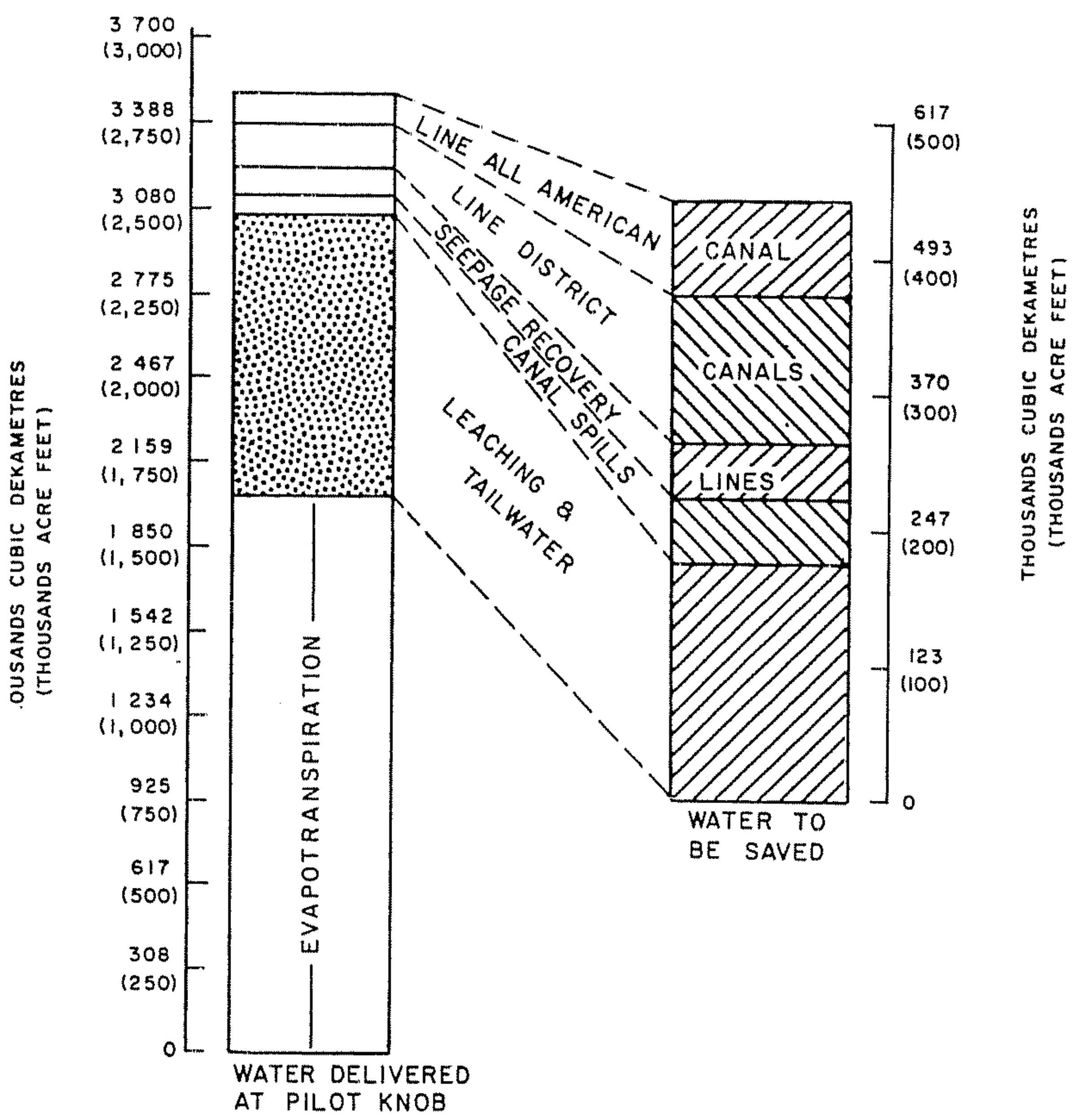


FIGURE 8 - ESTIMATED WATER SAVING BY CATEGORY

EPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1981 of the quantities of water delivered and water saved.

It appears reasonable that the District can accomplish the task of lining main and lateral canals, installing seepage recovery lines, and reducing canal spills. The combined annual savings would be about 234 000 cubic dekametres (190,000 acre-feet). However, lining the All-American Canal from Pilot Knob to the East Highline Canal to save 86 000 cubic dekametres (70,000 acre-feet) would be a relatively expensive project for the District to undertake.

The less expensive more productive projects should be given higher priority. Table 14 shows the suggested priorities for the various means of saving water and Figure 9 gives the relative costs.

By saving the 234 000 cubic dekametres (190,000 acre-feet), the District's conveyance system would have an efficiency rating of 98 percent, as compared to the present 92 percent shown on Table 4.

Also, the present average District irrigation efficiency of 66 percent and unit irrigation efficiency of 75 percent could be reasonably increased to 75 and 82 percent, respectively, through an increase in utilization of delivered water by holding tailwater to 15 percent of deliveries and leach water to 15 percent of ET and eliminating reject water. This would save at least 220 000 cubic dekametres (178,000 acre-feet) of water annually.

Thus, without lining the All-American Canal, the District and the individual farmers can save 454 000 cubic dekametres (368,000 acre-feet) annually.

It should be noted that a significant factor is the need to accelerate the installation of facilities that will help conserve water now being wasted. The key to this is financing.

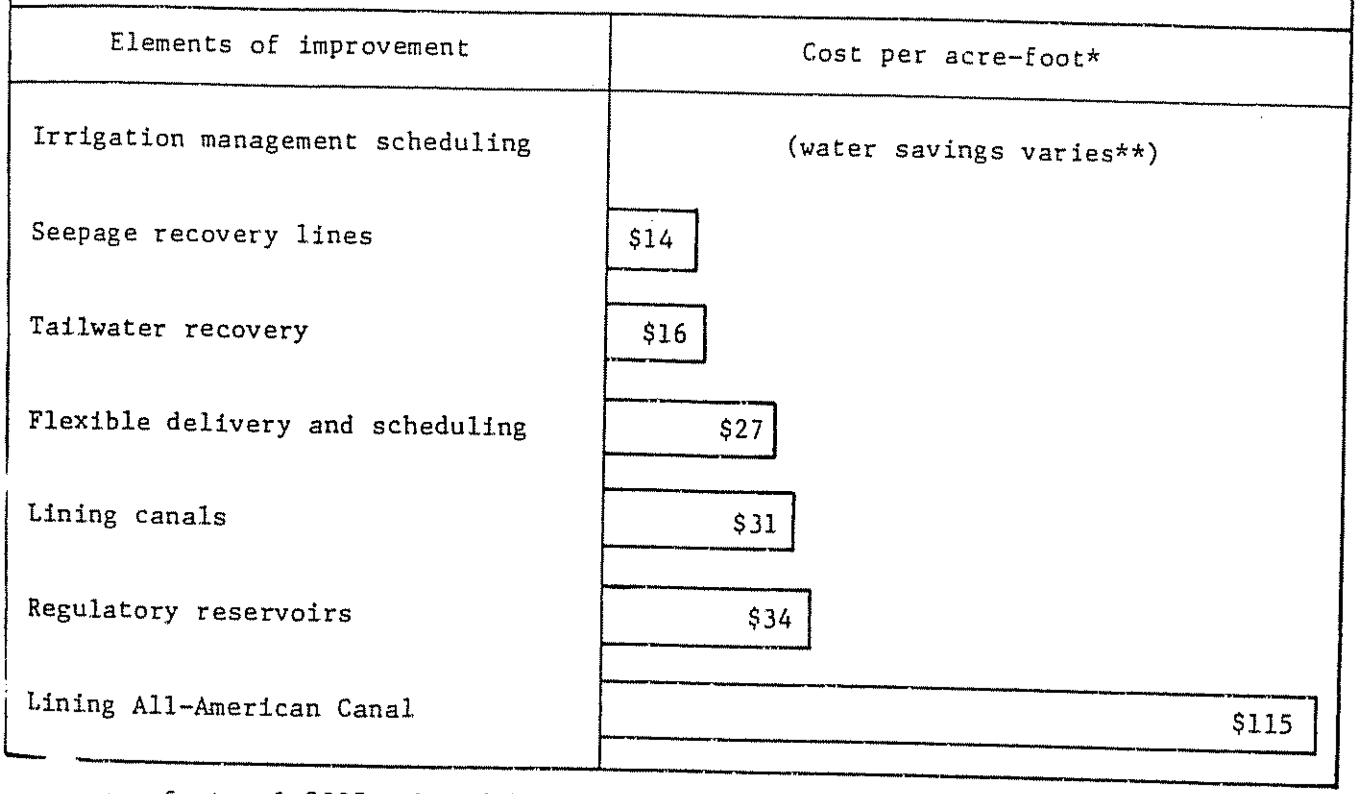
The District's posture on financing projects appears to be a "pay as you go" philosophy. The District will be investing about $5 million annually in conservation work, which could be used to finance a large block of capital funds (bonds) for early construction of needed facilities.

Early construction can also help avoid the ravages of inflation suffered by the "pay as you go" method of financing.

TABLE 14
SUGGESTED PRIORITIES OF
WATER CONSERVATION IMPROVEMENTS

PRIORITY 1 Non-structural	1. More flexible deliveries 2. Improve on-farm irrigation techniques 3. Expand use of irrigation management scheduling
PRIORITY 2 Structural	1. Line main canals and laterals 2. Expand seepage recovery system 3. Construct more regulatory reservoirs 4. Expand electronic monitoring controls 5. Expand use of tailwater recovery systems
PRIORITY 3 Structural	1. Line All-American Canal

FIGURE 9 - COST OF WATER SAVED BY SUGGESTED IMPROVEMENTS



*1 acre-foot = 1.2335 cubic dekametre
**Cost per acre (.4047 hectare) = $12

Evaluation of Improvements

Table 15 gives a concise summary of the information compiled in this investigation as related to the water losses that have been identified. The cost estimates are from various sources, as described elsewhere in this report, and may not be of a common price index, equal reliability, or equal accuracy. Table 16 shows in a tabular form whether the suggested improvements meet the test, set forth in Chapter III, of reasonableness of use for water saved.

Effects on Fisheries and Wildlife

Reducing inflow to the Salton Sea by 340 000 cubic dekametres (276,000 acre-feet) annually would significantly lower its water surface, as shown in Table 12. In addition, there would be a corresponding increase in the salt content of the water, which could adversely affect the Sea's status as a fishery and wildlife habitat. These impacts should be considered in activating the water conservation measures described in this report.

TABLE 15
OPPORTUNITIES FOR

Elements of improvement	Improvements			
	Line All-American Canal*	Line main canals and laterals	Expand seepage recovery system	Construct more regulatory reservoirs
Current plan & projected completion	60 km (37 mi), no completion date	834 km (518 mi) at 48 km (30 mi)/yr. 17 years to complete	Length unknown; no completion date	Plans not firm; no com pletion dat
Cost of improvement	$108,000,000 (1979 dollars)	$1,500,000/yr; 17 years to complete	$250,000 per 1.6 km (1 mi); total unknown	$2,000,000/ reservoir; total unkno
Water saved annually	86 000 dam^3 (70,000 af)	136 000 dam^3 (110,000 af)	37 000 dam^3 (30,000 af)	A combinati 281 000 dam determine program.
Unit cost of water	$93/$dam^3$ ($115/af)	$25/$dam^3$*** ($31/af)	$11/$dam^3$*** ($14/af)	$28/$dam^3$*** ($34/af)
Energy impact	Minor	None	Minor	Potential f small hydro-generation
Barriers to implementation	No funds available; comparatively expensive	Need funds to accelerate completion	No plans; need funds to accelerate completion	Need funds t accelerate completion

* Pilot Knob to East Highline Canal
** Includes 220 000 dam^3 (178,000 af) of leaching water and tailwater and 62 000 da
*** Based on 30-year life and 12% interest

for saving water				
Expand electronic monitoring control	Provide more flexible deliveries	Improve on-farm irrigation techniques	Expand use of tailwater recovery	Expand use of IMS
None	None	None; requires individual effort	None for extensive use	District hiring staff to use neutron probes
Unknown; capital intensive for District	Up to $2,000,000/yr.	Unknown; variable	Unknown; capital intensive for farmers	Unknown; cost effective in most cases
of these programs for conserving water could save (228,000 af).** An operations plan is required to the most effective and economical level of development for each Each program should complement the others, not duplicate.				
Unknown	Variable	Unknown, variable	$\$6.50$ to $\$20/\text{dam}^3$ ($8 to $25/af)	Variable; probably less than $5/ha ($12/acre)
Minor	None	Minor	45 kWh/dam^3 (56 kWh/af)	None
No plans; need funds to accelerate completion	Need to hire new staff; cost burden to user	Farmer acceptance; need for education	Potential crop reduction from higher salinity water; higher cost for water	Farmer acceptance; need for education

(50,000 af) of canal spills.

TABLE 16
REASONABLENESS OF SUGGESTED IMPROVEMENTS
FOR SAVING WATER

Considerations in determining reasonableness of water use	Improvements for saving water								
	Line All-American Canal a/	Line main canals and laterals	Expand seepage recovery system	Construct more regulatory reservoirs	Expand electronic monitoring control	Provide more flexible deliveries	Improve on-farm irrigation techniques	Expand use of tailwater recovery	Expand use of IMS
Potential beneficiaries & uses	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Excess water now serving a reasonable and useful purpose	No	No	No	Yes b/	Yes b/	Yes b/	No b/	Yes b/	No
Probable benefits of water savings	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Amount of water required for current use	None	Some for Salton Sea and fisheries	Some for Salton Sea and fisheries	Some for operation	Some for operation	Some for operation	None	Some for operation	None
Amount and reasonableness of cost of saving water	$93 dam^3 ($115/af) Ag marginal M&I reasonable	$25/dam^3 ($31/af) Reasonable	$11/dam^3 ($14/af) Reasonable	$28/dam^3 ($34/af) Reasonable	Unknown	$18-27/dam^3 ($22-33/af) Reasonable	Unknown	$6.50 to $20/dam^3 ($8 to $25/af) Reasonable	$5/ha ($12/acre) Reasonable
Required methods are: conventional? reasonable?	Ag marginal M&I reasonable	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes c/	Yes Yes c/	Yes Yes
Physical plan or solution	Yes d/	Yes	Yes	Yes	Yes	Yes d/	Yes	Yes	Yes

a/ Pilot Knob to East Highline Canal
b/ Partial amount necessary as operational water
c/ In cases of excessive tailwater production
d/ Financing yet to be determined

APPENDIXES

APPENDIX A

LETTER OF JOHN JAMESON ELMORE, JUNE 17, 1980

JOHN JAMESON ELMORE
P.O. BOX 156
BRAWLEY, CALIFORNIA 92227

June 17, 1980

Mr. Ronald B. Robie
Director, California Water
Resources Department
1416 - 9th Street
Sacramento, California 95814

Re: Application for Department Investigation of Misuse of Water by the Imperial Irrigation District

Dear Mr. Robie:

California Administrative Code Title 23 Section 4001(a) provides that upon good cause shown by any interested person the Department of Water Resources shall investigate any misuse of water. Pursuant to that section, I am at this time requesting that the Department investigate the misue of water caused by the wasteful management and marketing practices of the Imperial Irrigation District.

I am a farmer with significant farmland acreage contiguous to the shores of the Salton Sea. As you are probably aware, the level of the Salton Sea has been rising over the past years, and significantly so in the last five years. This rise in height is having serious adverse consequences for me. It has been necessary, at great expense, for me to dike much of my farmland in order to avoid submergence of my property. Irrigation water will no longer drain naturally from much of my property mandating the use of pumps to remove excess water. If the sea continues to rise at its present rate, much of my farmland will be flooded and destroyed for agricultural purposes. Even if the flooding should eventually prove to be relatively short term in duration, the farmland flooded will have lost its productive value due to salt pollution from the highly salty Salton Sea waters.

JOHN JAMESON ELMORE
P.O. BOX 156
BRAWLEY, CALIFORNIA 92227

Based on my own information and experience, conversations with other farmers in the Valley, and a review of the public documents attached, I believe that the rapid increase in height of the Salton Sea has been due to the wasteful water management and marketing practices of the Imperial Irrigation District. Drainage from the Alamo and New Rivers and storm run-off do not account for the tremendous increase in the Sea height. The Imperial Irrigation District's water management and marketing practices misuse water by allowing wasteful, unreasonable, and unnecessary water drainage into the Sea as a result of the District's distribution and control of irrigation water. The elimination of the wasteful and unreasonable drainage would result in the conservation of valuable water resources and the simultaneous stabilization of the Salton Sea level height.

I believe the Imperial Irrigation District misuses water through its wasteful and unreasonable policies and practices which apparently include:

1. Maintaining canals in overly full conditions. In order to provide "quick" delivery service of irrigation water, canals are kept overly full to such an extent that overflow gates at the terminal ends of the canals are frequently spilled over. The use of the canals as "reservoirs" is inappropriate in light of the significant amount of spillage and waste.

2. Absence of reservoirs for regulation of canal flows. The absence of reservoirs causes unnecessary delivery of excess amounts of water producing spillovers and run-offs into the Salton Sea.

3. Excess water is often delivered to farmers' headgates resulting in excess tail water run-off from irrigated fields. Water should not be delivered in an amount greater than that actually needed by the farmers. Provisions should be made to divert water to other users when farmers miscalculate the amounts of water they actually need.

4. Absence of tail water recovery systems. Tail water run-off is currently draining directly into the Sea. Recovery systems would allow the capture of the run-off for productive use.

JOHN JAMESON ELMORE
P.O. BOX 156
BRAWLEY, CALIFORNIA 92227

5. Water must be ordered in 24 hour delivery intervals. The delivery cannot reasonably be terminated after the farmer receives sufficient amounts of water. Excess water from the 24 hour delivery drains unused into the Salton Sea. Other needy water users are not contacted to use excess water delivered during the required 24 hour period. Therefore, any miscalculations in estimating the amount of water needed by a farmer results in significant waste.

As support for my position that the water management and marketing practices of the Imperial Irrigation District causes wasteful, unreasonable, and unnecessary water run-off into the Salton Sea, I attach the following Exhibits:

Exhibit 1: Excerpt from a Report of Findings, Advisory Panel on Agricultural Water Conservation (May, 1979) dealing with the Imperial Basin.

Exhibit 2: Excerpt from Department of Water Resources Bulletin No. 198, Water Conservation in California (May, 1976) dealing with the Imperial Basin.

Exhibit 3: Affidavit of William S. Gookin, Water Engineering expert retained by business owners sueing the Imperial Irrigation District for the flooding of businesses adjacent to the Salton Sea.

I request that the Department of Water Resourcs conduct a thorough investigation of all the water management and marketing practices of the Imperial Irrigation District. I feel that significant conservation of water could result from such an investigation with the additional benefit of stabilizing the height of the Salton Sea.

Respectfully submitted,

John Elmore

John Elmore

State of California
Edmund G. Brown Jr., Governor
Resources Agency
Department of Water Resources

Advisory Panel on Agricultural Water Conservation

(May 1979)

* * *

Report of Findings

Co-Sponsors

Senate Committee on Agriculture and Water Resources

Assembly Committee on Water, Parks, and Wildlife

California Water Commission

California Energy Commission

Department of Food and Agriculture

State Water Resources Control Board

University of California

CHAPTER III. THE IMPERIAL BASIN
(Coachella and Imperial Valleys)

The Imperial Basin occupies the extreme southeastern portion of California, encompassing the Coachella and Imperial Valleys. The quality of ground water in the Coachella Valley is good; but the Imperial Valley ground water is generally unsuitable for domestic and irrigation purposes, and most crops are supplied with imported surface water.

Water Delivery and Application

This area (largely served by the Imperial Irrigation District and the Coachella Valley County Water District) is defined as the area tributary to the Salton Sea. Irrigation water is provided to approximately 235,000 hectares (580,000 acres). The water supply for the area is largely from the Colorado River through systems installed many years ago. Water supply for the area is approximately 4200 million cubic meters (3.4 million acre-feet). The amount of water now flowing into the Salton Sea from the Imperial and Coachella Valleys is approximately 1200 million cubic meters (1 million acre-feet) annually. On-farm irrigation efficiencies approximate 66 percent, whereas the basin efficiency is 50 percent. The low basin-efficiency reflects excessively large losses in the conveyance system and little reuse of water.

It appears there is an opportunity to reduce diversions to the Imperial Basin and to make some of the water currently flowing to the Salton Sea available for beneficial uses. This opportunity would in no way affect California's allocation of Colorado River water, and a reduction in the present non-beneficial uses would relieve the problem of rising water elevation in the Salton Sea. The desired elevation of the Salton Sea is a factor that must be recognized.

According to Department of Water Resources' figures, annual conveyance and distribution losses amount to 253 million cubic meters (205,000 acre-feet) in the Coachella Valley and 787 million cubic meters (638,000 acre-feet) in the Imperial Valley. These losses could be reduced substantially by lining canals and ditches, and through other structural improvements. Improved conveyance systems would encourage more efficient irrigation district management. Delivery methods should also be improved or modified as much as possible to increase efficient use of water on the farm. Accurate water measurements should be made, and records kept both at water district offices and on the farms. Measuring devices should be installed where they are not now used.

Concrete-lined ditches and water control and regulation devices can improve on-farm irrigation efficiencies, and the introduction of laser-controlled leveling (a land-leveling process that uses a laser beam sensor to regulate the slope of a field) offers an accurate means to prepare land for efficient irrigation. (Level basin irrigation has improved irrigation efficiencies in comparable areas of other states). Irrigation scheduling programs that coordinate district operations with the farmers' needs will provide the coordination needed to improve the districts' overall management efficiencies.

Incentives other than presently escalating water prices appear to be needed to conserve additional water within the valleys. The State should investigate the setting up of low-interest agricultural loans to improve both on-farm and off-farm conveyance and distribution systems. It is estimated that as much as 500 to 600 million cubic meters (400,000 to 500,000 acre-feet) of water in the Coachella and Imperial Valleys could annually be made available for other beneficial uses. To better define what savings can be accomplished, a site-specific study should be made in each of these valleys, and the most cost-effective measures should be identified before actual physical improvements are initiated.

Drainage Water Reuse in the Coachella and Imperial Valleys

Drainage water in the Imperial and Coachella Valleys consists of both surface and subsurface return flows from irrigated fields. Additionally, the drainage system also collects drainage water from Mexico. This water flows into the Salton Sea, where it ultimately evaporates. Each year, 1600 million cubic meters of water (1.3 million acre-feet), with an average salt content of 3000 milligrams per litre (3,000 parts per million), flow to the Salton Sea. A potential exists for reuse of some of this drainage water for irrigation of selected crop species that can produce good yields with saline waters. Increased irrigation efficiencies would reduce the water available for reuse. Some flow of drainage water to the Sea would still occur, although at a higher salt concentration.

From a technological point of view, reuse of drainage water can probably be implemented faster than irrigation efficiencies can be improved. Application for drainage water to land already under irrigation can directly reduce the diversions by the districts from the Colorado River. The net effects of this practice would be a lower quantity flow of saltier water to the Salton Sea and reduced diversions of higher quality water. The Metropolitan Water District could provide a reuse incentive by purchasing part of the Coachella and Imperial Valleys' water rights. Yet some caution is warranted, since the drainage water from Mexico may contain untreated sewage.

WATER CONSERVATION

In California

May 1976

save
water
DWR

BULLETIN No. 198

STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES

TABLE 25

SOUTH LAHONTAN HYDROLOGIC STUDY AREA
PRACTICES TO INCREASE THE EFFECTIVENESS OF AGRICULTURAL WATER USE

Practice	Opportunity for Water Saving	Agricultural Viewpoint		Fish-Wildlife-Recreation Viewpoint		Comments
		Positive	Negative	Positive	Negative	
Sprinkler irrigation.	Slight to moderate	Would reduce applied water demand; increase crop yields.	Expensive. Would require more energy.	None.	Little impact	Fairly common now in Antelope Valley and Mojave River areas. Negative impact on conjunctive use in Mono-Owens area
Use of soil moisture indicators	Slight saving; would help irrigator time applications	Would increase yield; lower applied water needs.	Some cost involved for instrumentation.	None.	Little impact in this basin.	Standard for areas with good farm management practices
Control phreatophytes	Increases ground water recharge and available water supply.	Would save some water for recharges.	Some cost for vegetation removal and control.	None.	Would reduce a critical habitat for wildlife	Possible mainly in Owens Valley and along Mojave River
Canal and ditch lining.	Slight to moderate.	Would spread developed surface water over a larger area, thus reducing pumpage	None	None.	Might reduce some small areas of wetland habitat	Potential in Owens Valley

Colorado Desert Hydrologic Study Area

The Colorado Desert HSA in southeastern California is bordered by Arizona on the east and Mexico on the south. The HSA comprises 12 million acres (4.9 million square hectometres) of desert land with an almost year-round growing season, sparse rainfall, and very hot summers (Figure 18).

The 718,000 acres (290,900 square hectometres) currently under irrigation use about 3.2 million acre-feet (3,900 cubic hectometres) of water annually. Irrigation water is supplied by surface diversions from the Colorado River and from limited ground water pumping. An important limiting factor is the water quality. TDS ranges from 700 to 1,000 ppm, depending on the location of the diversion. Because of this highly saline water, adequate leaching is critical.

Present Agricultural Water Use

Agricultural operations are carried on in three principal locations: the Coachella, Imperial, and Palo Verde Valleys. Imperial Valley is the largest agricultural area, with extensive plantings of alfalfa, truck, and field crops. In addition to these crops, citrus is grown in the Palo Verde and Coachella Valleys.

Less than one-half percent of the area is sprinkler-irrigated; present irrigation practices are divided between border and furrow irrigation. The present HSA efficiency is estimated to be 66 percent (Table 26).

Opportunities for Water Savings

Table 27 lists practices that would increase the efficiency of agricultural water use in the Colorado Desert HSA.

Although drip and sprinkler irrigation could produce water savings, neither method is very popular at present because of the high initial capital cost and the fact that the cost of water (about $3 per acre-foot) does not encourage efficient use. On the

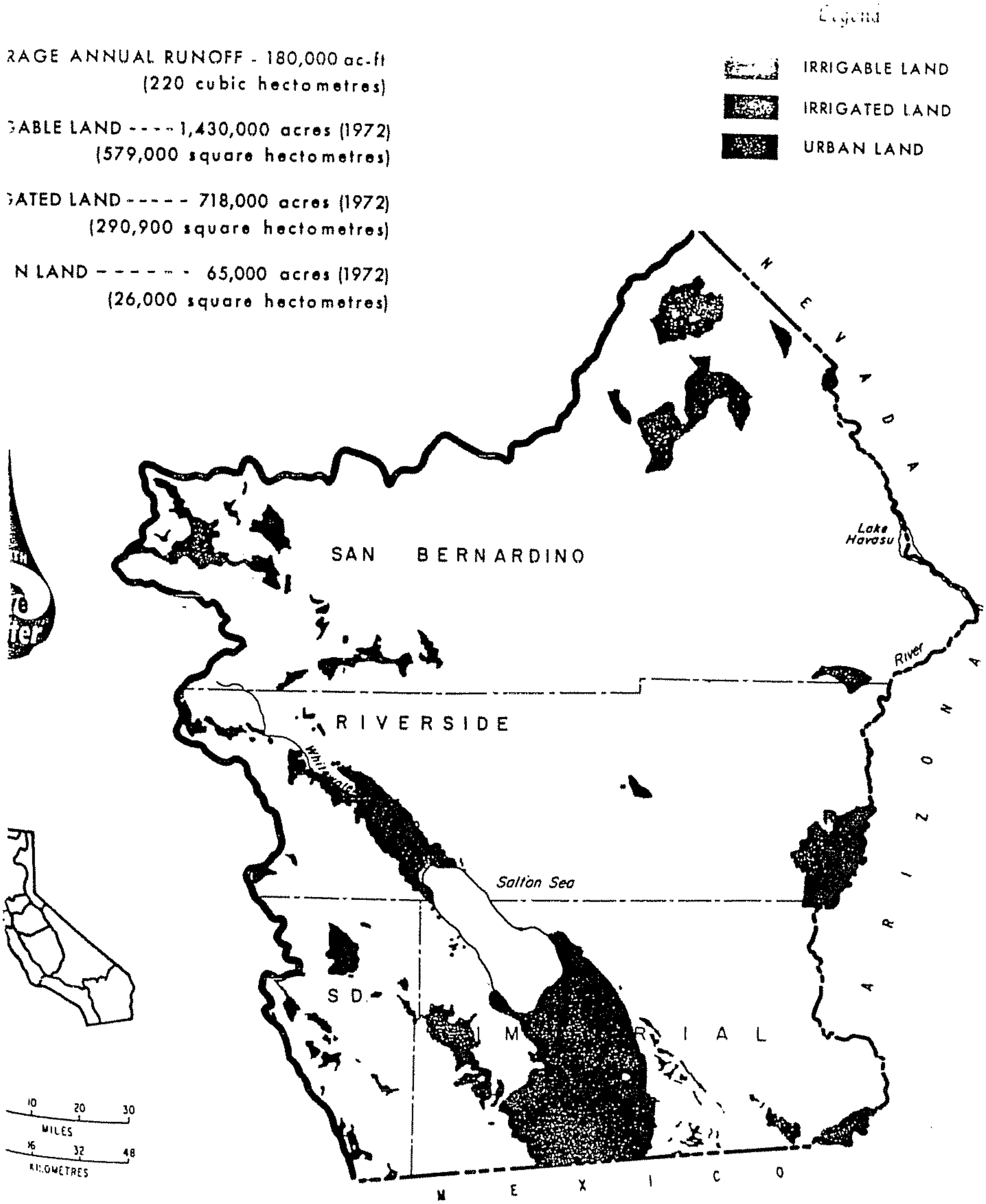


FIGURE 18
COLORADO DESERT HYDROLOGIC STUDY AREA

other hand, sprinklers not only help conserve water but also aid in seed germination, reduce root diseases, and can be used to both control frost in the spring and cool plants during the summer. Their use also eliminates certain forms of labor. Accordingly, the primary motivation for a change to sprinklers appears to be based on one or more of these reasons rather than on water conservation.

The use of sprinklers is increasing more rapidly in the Palo Verde Valley than in other areas of the HSA. In addition, the U.S. Bureau of Reclamation is operating a trial irrigation management service there. The objective is to accomplish better timing of water deliveries and application through the use of detailed climate and soils information. The Bureau's program is one of several aimed at reducing the salinity of the Colorado River.

On the other hand, improved irrigation efficiency in Palo Verde Valley may result in a problem. A small amount of drain water flowing out of the valley has been designated for cooling the Sun Desert Nuclear Power Plant, and more efficient irrigation practices would probably reduce that supply. However, if water from certain of the poorer quality level drains could be selectively used for the nuclear plant, overall water quality in the lower Colorado River could be improved.

Lining portions of the Coachella and All American Canals and district laterals could result in significant water savings, possibly as much as 250,000 acre-feet (300 cubic hectometres) per year.

In the Imperial Valley, sprinklers are not extensively used, but they are gaining acceptance for germination and cooling of lettuce.

Surface water deliveries in the Imperial Valley are made over a 24-hour period, and sometimes too much water is delivered to the farm headgate. Ditch tenders frequently have poor control over water distribution, and excess flows are lost in drainage ditches. Additional regulatory storage could reduce these operating losses.

Reductions of applied water in both Imperial and Coachella Valleys will reduce irrigation drainage, which feeds the Salton Sea. The Sea is critically affected by the quality and quantity of agricultural drainage inflow. Changes in irrigation practices could have severe environmental impact on the Sea by reducing inflow and at the same time increasing the inflow salinity.

TABLE 26

AGRICULTURAL LAND AND WATER USE
COLORADO DESERT HYDROLOGIC STUDY AREA
1972

Irrigated lands	Area		Average unit applied water		Range in unit applied water		Applied water	
	1,000 acres	square hectometres	feet	millimetres	feet	millimetres	1,000 acre-feet	cubic hectometres
Miscellaneous Field	164.9	66,700	3.7	1,100	1.3-6.6	400-2,000	603	744
Sugar Beets	61.1	24,700	4.1	1,200	2.2-6.6	670-2,000	252	311
Alfalfa	191.6	77,550	5.7	1,700	3.3-13.2	1,000-4,000	1,088	1,342
Pasture	28.5	11,500	7.6	2,300	—		216	266
Miscellaneous Truck	93.0	37,600	4.6	1,400	2.1-7.0	640-2,100	425	524
Tomatoes	2.4	970	4.6	1,400	—		11	14
Deciduous Orchard	0.6	240	3.3	1,000	—		2	2
Subtropical Orchard	33.8	13,700	6.1	1,900	6.0-9.0	1,800-2,700	207	255
Vineyard	7.9	3,200	5.4	1,600	—	—	43	53
Grain	135.0	54,600	2.7	820	1.2-4.1	370-1,200	370	456
Total	718.8[1]	290,760					3,217	3,967

Evapotranspiration of applied water (ETAW) = 2,621,000 acre-feet (3,233 cubic hectometres)[2]
Net basin demand = 3 966 000 acre-feet (4,892 cubic hectometres)

Hydrologic area efficiency = $\left(\frac{\text{ETAW}}{\text{net basin demand}} \times 100\right) = 66\%$

1 Includes double cropping
2 Includes 500 000 ac-ft leaching requirement

TABLE 27

COLORADO DESERT HYDROLOGIC STUDY AREA

PRACTICES TO INCREASE THE EFFECTIVENESS OF AGRICULTURAL WATER USE

	Opportunity for Water Saving	Agricultural Viewpoint		Fish-Wildlife-Recreation Viewpoint		Comments
		Positive	Negative	Positive	Negative	
	Moderate.	Would save water. Would also improve germination of crops and control of soil salinity.	Would require large capital investment; would increase energy needs.	None.	Would reduce runoff and wetland habitat.	The cost of water in most areas makes this measure economically impractical
	Small; application to a small acreage of subtropical orchard.	Would save some money.	Would involve very high capital investment.	None.	Same as above	Water costs currently too low to make this attractive
of	Moderate.	Would save water.	Would increase farm management costs.	None.	Would increase TDS in drains; dry up	Main problem is with reduced quality of drainage water.
/ in ıter	Higher opportunity.	Could irrigate more land with current water.	Would greatly increase operating costs to districts.	None.	Would reduce runoff to Salton Sea and increase salinity.	Greatest potential in Imperial Valley
manage- ices.	Good opportunity if farmers will cooperate.	Would save both water and energy	Would increase irrigation charge to farmers.	None.	Would reduce runoff and wetland habitat.	Irrigation automation can be incorporated into major irrigation district operations
d ing.	One of best off-farm measures; may save 10% of diverted water.	Would reduce system demand; provide more water for actual farm use.	Costly; would reduce water going to recharge ground water in some areas	None.	Would reduce riparian habitat.	Net effect of this practice needs to be carefully analyzed.
ed	Slight to moderate savings possible	Would save water by reducing application; less drainage to be managed.	Long-term effects not fully understood.	None.	Would tend to reduce riparian habitat by reducing drain water.	May have merit in this area by reducing large quantities of water currently used for leaching.
of phytes	Slight — not a problem here.	Would save some water.	None.	None.	Would eliminate wetland habitat.	Control should be highly selective

Statewide Summary

ɔ assess the potential statewide water savings ı agricultural water conservation, reasonably ıable water savings in each hydrologic study have been estimated and are summarized in e 28. Table 28 also shows that basin efficiency s from a low of 64 percent in the North Laıan HSA to 96 percent in the Tulare Basin. ıever, high efficiency is not necessarily deole; it must be weighed against water quality siderations; environmental factors including wildlife, and recreation needs; present water ndance; water cost; current water management ctices; and water rights.

o estimate feasible water savings in each of the rologic study areas, optimum HSA efficiencies e s ctively estimated on the basis of basin conditions (e.g., climate, crop types, soil conditions, water quality, water quantity, etc.). These optimum efficiencies are considered reasonably attainable if the on- and off-farm practices previously discussed are implemented. Tables 28 and 29 show present basin efficiency, describe the major practices that might be followed to produce actual water savings, and estimate the general range of water savings that might be achieved.

In some HSA's as in the Sacramento and San Joaquin Basins, very little actual water savings are possible through increased on-farm efficiency unless additional storage reservoirs or additional ground water recharge projects are developed to store the water conserved. This is because present reservoir storage is now committed to downstream or in-basin use. In addition, return flows from irrigation in the Sacramento and San Joaquin River Basins are actually part of the prime water supply going to the Delta to meet delta export demands, in-delta use, and delta outflow requirements. These return flows amount to 1,312,000 acre-feet (1,600 cubic hectometres) from the Sacramento Basin and 729,000 acre-feet (890 cubic hectometres) from the San Joaquin Basin

These statewide estimates of potential water savings are admittedly subjective. However, they [illegible] pacts of agricultural water conservation on [illegible] prime water supply. As discussed in the introduction to this chapter, even though actual water saving may not be great in some areas, improvements in irrigation practices can allow different management of the water resources to accomplish additional objectives, such as increased or re-regulated in-stream flows or energy savings. These opportunities need to be identified through case studies of specific areas throughout the State.

TABLE 28

1972 WATER USE EFFICIENCY AND OPPORTUNITIES FOR WATER SAVINGS BY AGRICULTURE IN THE ELEVEN HYDROLOGIC STUDY AREAS OF CALIFORNIA

Hydrologic Study Area	Irrigated Land		Applied Water		Evapotranspiration of Applied Water		Net Basin Demand		Present Basin Efficiency	Optimized Basin Efficiency	Possible Water Savings	
	1,000 acres	square hectometres	1,000 ac-ft	cubic hectometres	1,000 ac-ft	cubic hectometres	1,000 ac-ft	cubic hectometres	Percent	Percent	1,000 ac-ft	cubic hectometres
North Coastal	249	101,870	707	870	441	544	595	734	74	80	40	49
San Francisco Bay	105	42,640	249	306	172	212	245	302	70	85	40	49
Central Coastal	449	181,770	1,025	1,259	644	794	780	962	83	No increase recommended	0	0
South Coastal	431	174,640	922	1,136	646	797	760	937	85	No increase recommended	0	0
Sacramento Basin	1,530	619,250	6,017	7,423	3,487	4,301	5,174	6,382	67	75	520[1]	641[1]
Delta-Central Sierra	828	334,900	2,474	3,052	1,671	2,061	2,085	2,572	80	Recommend only minor change	0	0
San Joaquin Basin	1,364	551,800	5,446	6,717	3,248	4,006	4,466	5,509	73	75	110[2]	135[2]
Tulare Basin	2,166	1,281,400	10,888	13,428	6,784	8,368	7,079	8,732	96	Decrease to 90	-460[3]	-567[3]
North Lahontan	135	54,780	420	518	252	311	393	485	64	75	60	74
South Lahontan	78	31,360	306	378	204	251	225	277	91	No increase recommended	0	0
Colorado Desert	719	290,760	3,217	3,967	2,621	3,233	3,966	4,892	66	73	400	[illegible]

1. Theoretical saving; possible only by increasing ground water and/or surface water storage; does not include possible short-term ground water overdraft
2. Would need to improve distribution of present water supplies within basin to offset local ground water overdraft.
3. Would need to import more water, or reduce ETAW by converting to low-water-using crops or by reducing irrigated acreage.

TABLE 29

PRACTICES TO INCREASE THE EFFECTIVENESS OF AGRICULTURAL WATER USE
SUMMARY – ALL HYDROLOGIC STUDY AREAS

logic Area	Present Basin Efficiency (percent)	Optimized Basin Efficiency (percent)	Major Reason for Change	Major Conservation Practices
Coastal	74	80	Increase fish flows, provide more agricultural water.	Conjunctive use of surface and ground water, ditch lining
ancisco Bay	70	85	Increase irrigation supply	Improve delivery and reuse systems, increase use of ground water.
l Coastal	83	No increase recommended.	Highly efficient at present	Need to improve ground water basin management for supply and salt balance.
Coastal	85	No increase recommended.	Highly efficient at present.	Large increases in drip irrigation may allow acreage increases within present water supplies.
nento Basin	67	75	Conserve existing water supplies, improve total basin water management.	Institutional arrangements, district water management, conjunctive use of surface and ground water. Additional off-stream storage needed.
Central Sierra	80	Only minor improvements recommended.	Correct overdraft in eastern San Joaquin County.	Increase surface supplies, decrease ground water extraction
aquin Basin	73	75	Lower water table in selected areas. Improve efficiency of applied water use, decrease local ground water overdraft.	Improve irrigation management on-farm and by districts. Line canals
Bay	96	Lower to 90	Reduce ground water overdraft, decrease rate of salt buildup	Moratorium on further ground water extraction, land use control, increase basin import.
Lahontan	64	75	Increase available water supply, conserve spring runoff	Conjunctive surface-ground water operation, increase recharge, line ditches
Lahontan	90	Small increase recommended	Reduce need to pump ground water in Owens Valley	Increase use of sprinklers; line ditches and canals in Owens Valley.
ado Desert	66	73	Increase present supply, optimize salt balance	Line canals. Improve irrigation management.

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UNITED STATES DISTRICT COURT

SOUTHERN DISTRICT OF CALIFORNIA

SALTON BAY MARINA, et al., Plaintiffs, vs. IMPERIAL IRRIGATION DISTRICT et al., Defendants.	Civil Action No. 76-1095-T

AFFIDAVIT OF WILLIAM S. GOOKIN

IN SUPPORT OF PLAINTIFFS' MOTION

FOR PRELIMINRY INJUNCTION

State of Arizona)
) ss.
County of Maricopa)

WILLIAM S. GOOKIN, being first duly sworn, deposes a[illegible] says:

1. I am a registered Professional Engineer in Arizo[illegible] California, and other states. My resume is attached as Exhibi[illegible] "A" and incorporated herein by reference as though fully set f[illegible]

0 8

It sets forth my experience with various water districts and governmental agencies.

2. At the request of Lowell F. Sutherland, I conducted a series of studies to determine the causes of the rise in the level of the Salton Sea, which after approximately ten years' stabilization at about 231 feet below sea level has risen steadily since 1973. In the course of these studies I reviewed a document prepared by the Imperial Irrigation District identified as Exhibit 12, a copy of which is attached to this affidavit. Exhibit 12 contains water flow and water quality records for several locations throughout the District, including the All American Canal below Drop No. 1, and the Alamo and New Rivers both at the Mexican border and at the points where these rivers enter the Salton Sea. These measurements are important because according to the records of the Imperial Irrigation District, most of the water diverted into the Salton Sea by way of the Imperial Irrigation District is carried to the Sea by the New and Alamo Rivers. (A map showing the I.I.D. system is attached as Exhibit "B.") The Exhibit also reports the quality of leaching water, which is irrigation water used to flush soluable minerals away from the root zone of crops, at nine locations throughout the District.

3. Leaching water is necessary for agriculture in the Imperial Valley, because minerals from the irrigation water itself accumulate in the soil as the water evaporates. If the minerals were not flushed away from the roots of growing crops, the soil

would eventually become unsuitable for farming.

4. Exhibit 12 reveals that, in almost every quarter during the ten years used for this study, the water quality of the New River improved from the Mexican border to the Salton Sea outlet. The boundary quality was about 4600 parts per million (ppm) of dissolved minerals while the Salton Sea outlet quality averaged 3400 ppm.

5. Exhibit 12 also reveals that the Alamo River degrades in quality slightly, averaging 2000 ppm at the border and 2600 ppm at the Salton Sea.

6. The leach water, according to Exhibit 12, averaged 10,700 ppm dissolved minerals. If it were the only water added in Imperial Valley to the flows of the two rivers, their quality should be much worse, that is, much higher in dissolved minerals at the points where these rivers enter the Salton Sea. Reduction of the water quality to the concentrations set forth above requires large quantities of water containing fewer parts per million of dissolved solids, thereby diluting the concentration in the leaching water.

7. Based on a review of other documents and publications, and on my familiarity with the area, I am of the opinion that precipitation and groundwater cannot possibly account for the dilution of the leaching water. The documents and publications I have reviewed include documents provided by the Imperial Irrigation District to Mr. Sutherland; U. S. Geological Survey Professional Paper 486-C, written by A. G. Hely, G. H. Hughes

d B. Irelan in 1966; records of the Department of the Interior's Salton Sea Project, published in 1974; and "Salinity Control Study Salton Sea Project" written by M. Goldsmith and published in 1971.

8. Exhibit 12 reveals that the water in the All American Canal, which supplies all the canal water in the I.I.D. system, averages between 850 and 900 ppm dissolved minerals.

9. Imperial Irrigation District usually provides next-day deliveries of water and requires its customers to accept delivery in 24-hour increments, that is, the farmer must draw water from the canal for 24, 48, 72, etc., hours continuously. Based on my experience and familiarity with the operations of other water districts throughout the West, I know these to be unusual, if not unique, practices, both of which encourage waste of water.

10. The next-day delivery policy encourages waste of water because the Imperial Irrigation District is a gravity system, in which water flows downhill generally from south to north. The District has little or no reservoir capacity and in order to provide next-day delivery must keep its canals full or nearly full at all times. If the canals are continuously full, they must frequently spill, since water will continually move down the slope to the low point of the canal, which is the spill gate.

11. The 24-hour increment policy encourages waste of water because it requires the customer to estimate the amount of water he needs and then take the water at such a flow that he

will obtain his estimated volume at the end of a 24-hour increment. If he learns during irrigation that his estimate was wrong, he can do nothing to correct it. If more than 15% of his total water order runs off his field, the Imperial Irrigation District allegedly will fine him for wasting water; and yet ... District personnel will not adjust his headgate to modify or s[illegible] the flow of water more than once in 24 hours. Because the Dist[illegible] does not coordinate water orders among customers served by the same canal, there is generally not another water customer stand[illegible] by who could absorb any excess water ordered. This is a gross[illegible] wasteful practice unusual among Western irrigation districts.

12. The only explanation for the dilution of dissol[illegible] minerals in the New and Alamo Rivers is that large amounts of fresh water enter the rivers directly from the Imperial Irriga[illegible] District canals without ever being applied to farmland. I determined the proportions of fresh canal water and leaching water in the New and Alamo Rivers using the following forumula:

Q^1 (Quality of Water Entering the Salton Sea)=

X (Quality of All American Canal Water) +

Y (Quality of Leaching Water) +

Z (Quality of Rivers at Mexican Border)

In this formula, Q^1 represents the flow, expressed cubic feet per second, at the Salton Sea; and both flow and quality appear on Exhibit 12. Z represents that percentage of the outflow, Q^1, which entered the rivers from Mexico, and a[illegible] flow and quality at the border likewise are given. The [illegible] of the All American Canal water is given. I calculated the quality of the leaching water from the nine data points reported on Exhibit 12, and these ranged from a high of 31,301 ppm to a low of 510 ppm. X represents that percentage of the total outflow Q^1, which comprises All American Canal water, and Y represents that percentage of the total outflow, Q^1, which was leaching water.

I calculated the values of X, Y, and Z for each of the 40 quarters shown on Exhibit 12, and then averaged these values to calculate mean percentages for the ten-year period as follows:

	Mexican %	All American %	Leaching %
Alamo River	0.69	82.35	16.96
New River	24.68	64.01	11.31

13. Disregarding water from Mexico and comparing only the All American Canal water to the leaching water, which together represent the total Imperial Irrigation District inflow into the Salton Sea, I conclude that 84% of the water which enters the Salton Sea through the Imperial Irrigation District has never been applied to farmland.

14. I checked my conclusion against a study received in evidence as Arizona Exhibit No. 409 in the case of <u>Arizona v. California</u> (1963) 373 U.S. 546. In that study the surface inflow to the Salton Sea was found to be 81.4 percent Colorado River water, unpolluted by the addition of minerals, and 18.6 percent leaching water. Arizona Exhibit 409 used a completely different and independant method of determining these values.

15. Based on my review of the sources outlined in Paragraph 7 above, I calculate that 84% of Imperial Irrigation District's contribution to the Salton Sea would measure about 966,000 acre-feet of water per year. I have calculated and attached to this affidavit as Exhibit "D" a table showing how reduction of this 84% to various lower percentages would affect the surface elevation of the Salton Sea. Reducing the fresh-water inflow during the course of this litigation by eliminatin unnecessary spillage and by curtailing wasteful irrigation prac tices would have immediate effect toward restoring the Salton Sea to its previous stable level. My calculations indicate tha Imperial Irrigation District inflow exerts the greatest effect on the surface and volume of the Salton Sea of any contributing source, and that controls on that input would be the most effective.

16. I do not believe that substantial reductions in water escaping from the I.I.D.'s irrigation system would impose any significant burden on the defendant. Perhaps the easiest method of reducing spillage would be to lower the levels of wa in District canals, thereby eliminating their reservoir functio This would require the District's customers to wait longer for delivery of water after placing orders, but it would not requ increases in personnel or new equipment. The I.I.D. would sim order water from the Bureau of Reclamation at Imperial Dam and deliver that water when it entered the I.I.D.'s system, rather than keeping its system full at all times. Another m

would be to instruct District personnel to report spills and to take action to correct or prevent them, although I understand that the District claims to be doing so now.

17. The District could also virtually eliminate spillage by scheduling water deliveries to customers along the same canal sequentially, so that a second customer could begin to take water from the canal as soon as the first customer completes his irrigation.

18. Another practice which would reduce unnecessary water waste would be to end water deliveries when irrigation demands are met. As an alternative, the time intervals at which deliveries can be scheduled could be shortened, i.e. allow the deliveries to be made for 8-hour periods, or 4-hour periods, to permit the customer greater flexibility in ordering. Pump-back systems could be used to pick up acceptable-quality excess water which escapes an irrigator. Pump-back systems of this type are common throughout the Southwest.

William S. Gookin

WILLIAM S. GOOKIN

Sworn to before me this 12th day of October, 1979.

[illegible signature]

Notary Public [illegible]

EXHIBITS TO AFFIDAVIT OF WILLIAM S. GOOKIN

Exhibit A	-	Resume of W. S. Gookin
Exhibit B	-	Map of I.I.D. Canal System
Exhibit C	-	I.I.D. Exhibit 12
Exhibit D	-	Effect of Reduction of Inflow on Water Surface Elevation

E .HIBIT D

FRESH WATER % OF AVG. ANN. IID INFLOW	FRESH WATER INFLOW IN	TOTAL IID INFLOW (ACRE-FEET)	WATER SURFACE ELEVATIONS 5-YEAR	10-YEAR	30 YEAR	100-YEAR
84	966,000	1,150,000	-229.47	-228.05	-225.51	-224.67
80	920,000	1,104,000	-227.82	-227.70	-227.47	-227.39
75	862,500	1,046,500	-228.84	-229.44	-230.55	-230.93
70	805,000	989,000	-229.86	-231.21	-233.75	-234.63
65	747,500	931,500	-230.90	-233.03	-236.49	-236.80
60	690,000	874,000	-231,95	-234.88	-238.60	-238.90
55	632,500	816,500	-233.02	-236.66	-240.46	-241.10
50	575,000	759,000	-234.10	-238.35	-243.01	-243.42
45	517,500	701,500	-235.19	-240.04	-245.44	-245.83
40	460,000	644,000	-236.27	-241.76	-247.98	-248.49
35	402,500	586,500	-237.34	-243.53	-250.68	-251.27
30	345,000	529,000	-238.43	-245.37	-253.57	-254.26
25	287,500	471,500	-239.52	-247.23	-256.67	-257.47
20	230,000	414,000	-240.63	-249.28	-260.01	-260.94
15	172,500	356,500	-241.76	-251.37	-263.65	-264.74
10	115,000	299,000	-242.93	-253.57	-267.62	-268.90
5	57,500	241,500	-244.13	-255.90	Sea almost empty	
0	-0-	184,000	-245.34	-258.34	Sea almost empty	

APPENDIX B

ORGANIZATIONS AND INDIVIDUALS CONTACTED DURING THE INVESTIGATION

ORGANIZATIONS AND INDIVIDUALS CONTACTED DURING THE INVESTIGATION

Date	Contact	Title	Organization-Location
0-21-80	J. D. Rhoades	Soil Scientist	USDA Salinity Lab, Riverside
0-21-80	Arthur Swajian	Executive Officer	State Water Resources Control Board, Colorado River Basin Region, Palm Desert
0-21-80	Ed McGrew	Farm Manager	Member IID Water Conservation Advisory Board
0-22-80	L. R. McGlocklin	Asst. to General Mgr.	Imperial Irrigation District
0-22-80	Frank Robinson	Assoc. Water Scientist	U.C. Davis, Meloland Res. Station
0-22-80	Douglas Welch	Soil Conservationist	USDA Soil Conservation Service, El Centro
0-22-80	Lowell Sutherland	Attorney-at-Law	Sutherland & Gerber, El Centro
0-27-80	Donald A. Twogood	General Manager	Imperial Irrigation District
0-27-80	J. Robert Wilson	Water Manager	Imperial Irrigation District
1-7	Darrell E. Byrd	Deputy Agricultural Commissioner	Imperial County Office of Agricultural Commissioner
1-18-80	Franklin F. Laemmlen	Farm Advisor	University of California Agricultural Extension, El Centro
1-24-80	Larry Gilbert	Farm Manager	IID Water Conservation Advisory Board
1-25-80	Keith Mayberry	Farm Advisor	University of California Agricultural Extension, El Centro
1-26-80	Lee Hermsmeier	Agricultural Engineer	Imperial Valley Conservation Research Center, USDA-ARS, Brawley
1-26-80	Michael C. Wallman	Secretary Manager	Imperial County Farm Bureau
1-26-80	Lloyd Heger	Farm Owner	El Centro
1-26-80	Bill Brandenberg	Farm Owner	IID Water Conservation Advisory Board

Date	Contact	Title	[illegible]
11-26-80	Stanley Mitosinka	Farm Manager	Holtville
11-26-80	J. P. McKim	Farm Owner	Imperial
11-26-80	Earl Brinkman	Farm Owner	El Centro
11-26-80	Mike Doran	Farm Owner	Brawley
11-26-80	Charles Westmoreland	Farm Owner	El Centro
11-26-80	Robert E. Shank	Farm Owner	Brawley
11-26-80	Dorothy Dahm	Representative	California Women for Agriculture
2-17-81	Leonard Seaton	President	Agricultural Technical Services, Bakersfield
2-17-81	Charles Corfman	Technician	Proctor Leveling and Contracting Company, Brawley
2-17-81	Clair Merrill	President	Merrill Ditch-Liners, Inc., El Centro
2-19-81	Chris Donabedian	Senior Engineer	Colorado River Board, Los Angeles
2-24-81	Dave Overvold	Hydraulic Engineer	U. S. Bureau of Reclamation, Boulder City, Nevada
4-2-81	Norman MacGillivray	Assoc. Land and Water Use Analyst	Department of Water Resources, San Joaquin District
4-2-81	John Glavinovich	Assoc. Land and Water Use Analyst	Department of Water Resources, Division of Planning, Sacramento
4-2-81	James Morris	Assoc. Engineer, Water Resources	Department of Water Resources, San Joaquin District
4-7-81	Les Stromberg	Farm Advisor	University of California Agricultural Extension, Fresno
7-21-81	Larry Dean	Project Director	U.S. Fish and Wildlife Service, Calipatria
7-21-81	Dana Long	Area Manager	Salton Sea State Recreation Area, Imperial County
7-21-81	Chris Gonzales	Area Manager	California Department of Fish and Game, Imperial Wildlife Area, Niland

APPENDIX C

REFERENCES

Appendix C

REFERENCES

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APPENDIX D

IMPERIAL IRRIGATION DISTRICT WATER CONSERVATION PROGRAMS AND WATER CONSERVATION ADVISORY BOARD BY-LAWS

Appendix I

THE 13-POINT AND 21-POINT WATER CONSERVATION PROGRAM OF THE IMPERIAL IRRIGATION DISTRICT

1 oint Water Conservation Program

Recognizing the seriousness of the water shortage the northern part of the State was experiencing, and wishing to cooperate in meeting this critical problem, Imperial Irrigation District in July 1976 supplemented its existing water conservation efforts with a stringent 13-point program. Included in the program are:

1. Construction of a water-regulating reservoir on the Westside Main Canal.
2. Reconstruction of farm outlet boxes, as required.
3. Employment of an adequate number of water-regulating personnel to effect more efficient deliveries, as the system will permit.
4. Daily inventory of surface field discharge, charging users who needlessly waste water an assessment for that day equal to three times the scheduled water rate.
5. Development of surface water evaporation ponds.
6. Preliminary studies for a regulating reservoir on the Central Main Canal.
7. Studying the feasibility of installing additional water recovery lines paralleling the main canals to increase salvage of seepage water now entering the drainage system and the Salton Sea.
8. Providing free drainage water to persons willing to pump and use same.
9. Continuing the concrete lining program.
10. Initiating a record of accrued water use per acre per parcel per annum through computerized billing.
11. Installation of radio equipment in all water-conservation-related vehicles to afford immediate communication with supervision.
12. Initiation of an irrigation management services program.
13. Delivery of water off-schedule when and wherever possible.

21-Point Water Conservation Program
(Revised Oct. 1, 1980)

1. The District shall establish a penalty of one hundred dollars ($100.00) for the unauthorized adjusting of delivery gates which results in a change in the amount of water being delivered.

   Furthermore, whenever a water order is in the process of being pumped through a sprinkler or gated pipe system and the operator-user experiences a mechanical failure of the subject equipment, said operator-user shall be permitted to discontinue his water delivery for a period of not more than three (3) hours. The free time permitted under this schedule shall be considered as separate instances but in no event shall the combined hours so considered exceed three (3) hours before a triple charge is to be assessed.

2. The concept of installing gate control devices of a standard design is recommended and supported, such devices to be installed on structures accommodating gates which are owned, operated and maintained, as well as regulated, under the jurisdiction of the District and its personnel.

3. Application of the assess- [illegible] of irrigation, with the following exceptions:

   (a) The percentages of surface runoff allowed when water is being used to irrigate plowed or flat unseeded ground shall be five percent (5%) for the last day of said irrigation; no measurable waste shall be allowed for any previous days.

   (b) When water is being run in furrows to germinate crop seeds and establish a stand, no assessment charge shall be made unless one of the two consecutive measurements showing fifteen percent (15%) or more runoff is made between 12:00 noon and 6:00 p.m.

4. In the event a water user is receiving more than his confirmed order, said surplus shall be subtracted from his surface runoff for the purpose of determining if his runoff is excessive.

5. In no event shall any water user be assessed unless his runoff is fifteen percent (15%) or more of his running order irrespective of the quantity of water the user is receiving.

6. Any surface runoff measurement made within four (4) hours after the District has reduced the quantity of water delivered shall apply to the order in effect before said change.

7. The application of an assessment charge based on waste measured after the delivery gate is closed shall apply on the same basis as when water was actually running. Any assessment made after the gate is closed shall be based on the order last running.

8. In no event shall the user pay more than triple the normal charge for water, except when he adjusts the delivery gate without permission.

9. All net proceeds from surface runoff assessment charges shall go into a special fund for conservation purposes other than the concrete lining of ditches.

10. All District personnel whose duties include checking of surface runoff will initial any waste assessment sheets issued.

11. Changes can be made for the last day of a run by notifying the District not later than 3:00 p.m. of the preceding day.

12. When a water user requests an adjustment in the quantity of water delivered not to exceed two (2) feet, the District shall be obliged to honor the same if it is within the ability of the District's system to accommodate such request and the water user notifies the zanjero in advance of beginning his daily run. The zanjero of said run shall obtain approval to make said change from his respective superior or section.

13. A reduction in the water order shall be made to apply to the last twelve (12) hours water is run, providing that the District is notified in advance but not later than 3:00 p.m. preceding the time the order is changed. No penalty shall be charged for said reduction as long as the same does not exceed fifty percent (50%) or five (5) feet of the order as confirmed, whichever is less. Water returned with notice after 3:00 p.m. or which exceeds the quantity that this rule authorizes shall be subject to an assessment equal to two times the regular water rate.

[illegible]
[illegible] whichever is less.

Ir[illegible]h heads can be ordered up to 3:00 p.m. of the day preceding the day of
[illegible]ery.

By notifying the District before 7:30 a.m. of the last day of a run, an order can be adjusted up to fifty percent (50%), without penalty.

One-day orders shall be checked by the appropriate District employees on the same basis as any other water order. For the application of the assessment charge, the first waste measurement shall not be made later than eighteen (18) hours after the beginning of the day's water delivery.

The District shall secure whatever additional radio equipment that is necessary to improve communications between the farmers and Water Department personnel.

The Water Department of the District shall make six (6) wastewater recorders available to be installed at various locations within the service area boundaries as defined.

The District shall prepare a monthly water information bulletin for distribution which shall include information submitted to the District by a committee to be appointed by the Water Conservation Advisory Board, and from other sources as required for the purpose of assisting the water user in using all water beneficially.

Routine canal cutouts shall be accomplished once every eight (8) weeks, except when special circumstances require more frequent cutouts.

BY-LAWS OF THE IMPERIAL IRRIGATION DISTRICT

WATER CONSERVATION ADVISORY BOARD

ARTICLE 1. PURPOSE

Section 1.01. The purpose for which this board is organized is to recommend to the board of directors of the Imperial Irrigation District and the Imperial Valley farming community an expaned program of irrigation efficiency in system operation and farming practices.

ARTICLE 2. MEMBERSHIP

Section 2.01. The committee shall consist of ten (10) regular members, all of whom shall have voting privileges.

Section 2.02. Two regular members and one alternate shall be appointed by each member of the Imperial Irrigation District board of directors from their respective water operating divisions. Regular members and alternates shall be engaged in farming.

Section 2.03. Alternates shall be subject to the same requirements for attendance at meetings as regular members, and shall have voting privileges in the absence of a regular member from the alternate's division and shall be the first choice for appointment to succeed a regular member from his division, whose term has expired.

Section 2.04. Two members of the Imperial Irrigation District board of directors and three District management representatives shall be appointed by the District board and shall serve as advisors to the regular advisory board members.

Section 2.05. Regular members shall serve for only one (1) , such term to be two (2) years, except that, by a vote of seven regular board members, the terms of not more than three (3) regular ers may be extended for an additional one (1) year. Alternates l serve until their successors are appointed by the Imperial gation District board of directors, but in no event less than two years. Advisors to the regular board members shall serve at the and pleasure of the Imperial Irrigation District board of directors.

Section 2.06. By vote of not less than seven (7) regular members, gular member may be removed from the board for any reason. Further, ny regular member fails to attend three (3) consecutive board meet- or five (5) meetings in any year during his term of office, his tion may be declared vacant by a majority of the remaining regular ers of the board.

Section 2.07. Alternates shall fill any vacancy on the advisory d, and shall serve for the remainder of the term during which the ncy occurred.

ARTICLE 3. MEETINGS

Section 3.01. Meetings of the advisory board shall be held in board room, located in the Executive Offices of the Imperial gation District, 1284 Main Street, El Centro, California.

Section 3.02. The first meeting of the advisory board shall eld on July 12, 1979, at 1:30 P.M., for the purpose of selecting officers and transacting such other business as may come before the meeting. Each year thereafter, at its regular meeting in July, the board shall select officers and reorganize itself as required by these By-Laws.

Section 3.03. Regular meetings shall be held on the second Thursday of each month, beginning with the month of August, 1979, at 1:30 P.M., unless such day falls on a legal holiday, in which event the regular meeting for that month shall be held at the same hour and place on the next succeeding day.

Section 3.04. Special meetings of the board may be called by the chairman, or, in his absence, the vice-chairman, or by a majority f the regular members of the board. Special meetings shall be held at the board's regular meeting place.

Section 3.05. Notices of regular and special meetings of the board shall be in postcard form, sent to each member, alternate, and advisor, by United States mail, and shall be given by the secretary or other person designated by the chairman. Notice of each regular meeting shall be mailed on the Friday preceding such meeting. Notice of special meetings shall be mailed at least 72 hours prior to the time of any such meeting.

Section 3.06. All meetings shall be held in compliance with the requirements of the Ralph M. Brown Act (Chapter 9, Division 2, Title 5 of the Government Code), and shall be open and public unless ne ise authorized by law.

Section 3.07. A quorum shall consist of a majority of the gular members holding office. In the absence of a quorum, a meeting the board may be adjourned from time to time by vote of a majority the regular members present, but no other business shall be transacted.

Section 3.08. Each regular member is entitled to one (1) vote each matter submitted to the meeting. Voting shall be by voice te, unless a regular member demands a roll call vote, in which event e secretary shall call the roll and duly record the votes of each ard member. There shall be no voting by mail or proxy voting.

Section 3.09. Meetings of the board shall be presided over the chairman, or, in his absence, the vice-chairman, or, in the ser-e of both, by a chairman chosen by a majority of the regular mbers present. The secretary shall act as secretary of all meetings. etings shall be governed by Roberts Rules of Order, as such Rules y be revised from time to time, insofar as such Rules are not in-nsistent with or in conflict with these By-Laws.

ARTICLE 4. OFFICERS

Section 4.01. The officers of the advisory board shall be a airman, a vice-chairman and a secretary.

Section 4.02. The chairman and vice-chairman shall be elected nually by the board from among its regular members, and may be removed ther with or without cause, by a majority of the board, at any time.

Section 4.03. The chairman shall preside at all meetings of the board, and shall, as required, serve ex officio as a member of all standing committees of the board.

Section 4.04. In the absence of the chairman, or in the event of his inability or refusal to act, the vice-chairman, shall perform all duties of the chairman, and when so acting shall have all powers of and be subject to all restrictions on the chairman.

Section 4.05. The secretary of the board of directors of the Imperial Irrigation District shall serve, ex officio, as the secretary of the advisory board. He shall not be a member of the said board, and shall have no voting privileges. He shall be responsible for certifying and keeping the original of these By-Laws, as amended or otherwise altered, and shall maintain the same at the Executive Offices of the Imperial Irrigation District, together with the book of minutes of all meetings of the board, recording therein the time and place of holding, whether regular or special, and the proceedings conducted at said meetings. He shall be responsible for giving all notices in accordance with the provisions of these By-Laws or as required by law.

ARTICLE 5. MISCELLANEOUS PROVISIONS

Section 5.01. Committees. The advisory board may designate two or more of its regular members to act as a committee, to investigate and report on such matters as the board deems appropriate. No act of any such committee shall be valid unless approved by vote of the board lf.

Section 5.02. Fiscal Year. For purposes of these By-Laws, business of the board shall be conducted on a fiscal year basis encing July 1st of each year. All terms of office shall be deemed egin on July 1st and end on June 30th.

Section 5.03. No Compensation or Expense Reimbursement. lar members shall receive no compensation, salary, or other neration for their service as regular members. Expenses incurred oard members, if any, in connection with their service, shall not eimbursed.

Section 5.04. Effective Date of By-Laws and Amendments. By-Laws l become effective upon their adoption by the advisory board, and oval by the District board of directors. Amendments may be adopted majority vote of the advisory board, subject to approval by the rict board of directors.

Section 5.05. Construction. As used in these By-Laws the uline gender includes the femine and neuter, singular number udes the plural, and the word "shall" is mandatory and the word " is permissive.

IN WITNESS WHEREOF, the undersigned secretary of the Water ervation Advisory Board of the Imperial Irrigation District has uted these By-Laws this _____ day of __________________, 1979.

SECRETARY, WATER CONSERVATION
ADVISORY BOARD

The undersigned, Secretary to the Board of Directors of the Imperial Irrigation District, hereby certify that the foregoing By-Laws for the Water Conservation Advisory Board of the Imperial Irrigation District, dated ______________________, 1979, were approved by the Board of Directors of the Imperial Irrigation District at a ______________________ meeting held on ______________________, 1979.

Dated: ______________________, 1979.

____
SECRETARY OF BOARD OF DIRECTORS
OF IMPERIAL IRRIGATION DISTRICT

112